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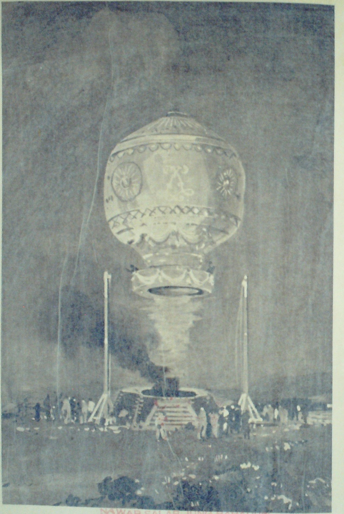

NAWAB SALAR JUNG BAHADUR

THE CONQUEST OF THE AIR.

The first hot-air Balloon, invented by the brothers Montgolfier (1783).

[*Frontispiece.*

POPULAR SCIENTIFIC RECREATIONS

By

Professor A. M. LOW, D. Sc.

Illustrated with 16 pages of Photographs and 100 Diagrams

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NAWAB SALAR JUNG BAHADUR

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INTRODUCTION

IT is not many years since chemistry and physics were comparatively unknown as subjects of primary education. Even to-day there are many famous schools where the men of to-morrow are encouraged to study Greek and Hebrew in preference to Science. But our ideas are rapidly changing, for the last twenty-five years have shown that Science is probably the most important study in the world and is likely to become of even greater consequence. The last decade has shown that the greatest discovery of all is our lamentable ignorance of most basic facts in life.

In this book, I have tried to show that Science is no dull affair of equations, calculations and formulæ, but a fascinating subject which attempts to explain the world about us and that enables us better to understand its meaning and beauty. To-day, you cannot escape Science. If it is your desire to appreciate the beauty of the sunset, the glorious colours of an oil puddle in the road or the crystals of frost on the window pane, you must know just a little of the principles of Science.

Every man, woman and child should be encouraged to learn something about chemistry, physics and other branches of technical knowledge. Especially should they be asked to study these subjects from a practical point of view. The actual performance of experiments is often more interesting than theory and can teach lessons of the greatest value. The essence of Science, which distinguishes it from all other studies, is that experiment may precede theory. The scientist observes certain phenomena and attempts to build a theory that will fit the facts as he knows them rather than to fit his experiments to any assumption. I think that of all the lessons taught by Science the most valuable is that of the necessity for an open mind. It is because a technical education insists upon this point that the theories of yesterday can be usefully supplanted by recent discoveries that seem better to fit the new facts of any case.

The experiments in this book have been designed to be at once entertaining and illustrative of scientific laws; they can be carried out successfully by anyone who follows the instructions carefully. Each operation does not take for granted any knowledge of Science, but its success will depend on the use of a scientific method of carrying it into effect. Science is little more than organised common-sense, and therefore there need be no difficulties for those gifted with a reasonable amount of this useful commodity.

Anyone who conducts all these experiments will unconsciously acquire a reasonably good working knowledge of chemistry, physics and allied subjects. Their knowledge will be, in many ways, superior to that obtained from standard text-books, because these experiments will be performed for "fun"—for the pure love of Science and interest in natural phenomena—as distinct from experiments made and theories learned with the object of struggling through an examination. Neither will the basic principles of each result be lost when it should chance to differ, however slightly, from the expected conclusion.

NAWAB SALAR JUNG BAHADUR

I have, in every case, purposely explained the reason for the startling or interesting effects produced. To be content to change "water" into "wine," for instance, without understanding something of the nature of the change is, I believe, definitely bad. Whenever I have visited the Science Museum at South Kensington, I have always been struck by the number of people—men, women and children—who are fascinated by the idea of "pressing the

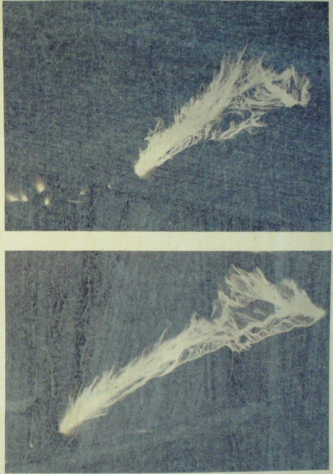
button." Unless some attempt is made to understand the results, I think that "pressing the button" is bad Science. Worse still, it is apt to suggest that standardisation is a help to progress.

There are no dangerous experiments in this book. At the same time, all chemicals should be handled with care, and there must be no indiscriminate mixing or tasting. Every bottle of chemicals should be carefully labelled. If you follow the directions, there will be no chance of an accident.

I offer no apology for the homely nature of much of the apparatus I recommend and describe. I want to bring home the point that Science is an everyday affair that can be studied in the home or in the street as effectively as in the highly-equipped laboratory. No doubt many of the experiments will be more easily performed if a few pence are expended on simple apparatus, which can be bought from any drug store, but the vast majority of the experiments can be conducted with nothing more costly than the ordinary articles to be found in every kitchen. Occasionally it may be necessary to buy the pure chemical, instead of the commercial product usually found in kitchens, but in these cases I give the explanation.

There is no need to start solemnly at page one and work through the experiments from cover to cover. Although each section is complete in itself, the book can be opened at random and the experiments performed in any order, as the apparatus is available. If you wish to give a demonstration of the magic of Science to your friends, choose a dozen of the more striking experiments, prepare your apparatus carefully beforehand and go ahead in any order that appeals to you.

I have hinted occasionally that to those who do not understand the principles involved, many of the experiments will appear to be "magic." I have given performances of this "magic" myself, but I have always made a point of explaining the phenomena afterwards. To use Science for purposes of deception is very easy, but savours of the alchemist or fraudulent medium. By all means surprise your friends with some of the experiments, but in fairness to them, explain afterwards. For this reason I have inserted in this book very little savouring of "conjuring" or dependent upon sleight of hand. Some of the experiments are very old, but none the less interesting for that. I cannot lay claim to inventing every experiment in the book, but in many cases I have taken phenomena well known in the laboratory and adapted them for use in the home.



ARTIFICIAL LIGHTNING.

1. A 1,000,000-volts "flash-over." 2. A 1,500,000-volts spark. The results of investigations with artificial lightning are applied to the manufacture of electric transformers and other high-voltage transmission line apparatus.

[*Facing page 14.*

ELECTRICAL EXPERIMENTS

CHAPTER I

ELECTRICAL EXPERIMENTS

MAGNETS

ALTHOUGH electricity is, comparatively speaking, a newly discovered "force," magnetism has been known for thousands of years, and the north-pointing compass needle was used by sailors and travellers before the dawn of what we call civilization. The magnet used by these sailors was made of lodestone, a natural mineral which has the property of magnetism and of pointing to the magnetic north when suitably suspended.

For the experiments with magnets you will require perhaps half a dozen of different sizes and shapes. These can be bought for a shilling or two, but if you obtain a large magnet, a number of others can be made out of knitting needles and other steel objects.

Magnet and a Knitting Needle.—In the first instance, take a horseshoe magnet and a knitting needle. The magnet will attract the needle, but, unless it is in contact with the magnet, the needle will not attract iron pins or ordinary steel objects. Now draw the knitting needle half a dozen times over one end of the magnet, always stroking it in the same way. Then put the needle to a pin or fine sewing needle, and you will see attraction. You have turned the knitting needle into a magnet. Give it a sharp blow or two with a hammer, and again apply it to the pin. It no longer attracts. Vibration or a blow destroys much of the property of magnetism.

You can apply this knowledge to an amusing piece of deception. After magnetising a knitting needle, pick up an iron pin with it and ask a friend if he thinks he could do the same. You will certainly get the answer "Yes," but as you offer the needle to your friend, drop it apparently by accident. The blow on the floor will destroy the magnetic power, and when he applies the needle to the pin, he will find that it no longer lifts it. If he asks you to try again, you will have to draw the needle over the arm of the magnet again, but as long as you do it nonchalantly, it may not be noticed, and you will be able to pick up the pin again where others have failed. You should be certain to explain to him the deception afterwards!

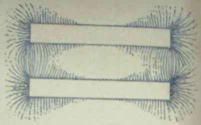


Fig. 1. Lines of force.

Magnets and Iron Filings (Lines of Force).—For a few pence you can purchase a good supply of iron filings, or if you cannot obtain them, a supply can be made, if you have the patience and energy, by filing a piece of soft iron and catching the minute pieces on paper. Scatter the filings over the paper and then lay a bar magnet in the middle. The filings will suddenly jump into life and in less than a second will take up definite positions (Fig. 1). The magnet is usually best placed under the paper.

You will find that the filings form "streaky" lines round both ends of the magnet, while they are attracted very little to the middle. Repeat the experiment with a horseshoe magnet and you will find again that the filings form patterns round the end of the arms, remaining unattracted by the middle (Fig. 2). The lines which the filings form are called "lines of force," and you can record them on the paper by drawing the outline of the magnet in pencil and then coating the paper very thinly with wax. Once the filings are in place, you have simply to warm the paper from beneath for a second or two and the wax will melt.

When it cools, it will hold the filings in place and you will have a permanent record of the lines of force of the magnet. Another method is to use some sensitive daylight printing paper which can be exposed to the sun while the filings are in position.

These small particles of iron show how the infinitely smaller particles forming the substance of a large bar arrange themselves so that they turn the body of the metal into a magnet.

The Poles of a Magnet.—Iron filings provide a very easy way of watching the working of magnets. The ends of the magnet, where the power of attraction is concentrated, are called the *poles*; every magnet has a north and a south pole. If you magnetize a fine sewing needle and grease it so that it floats in a bowl of water, you will find that it always lies in one direction. Whatever you may do to the needle, it will eventually always take up the same position, pointing north and south. This is the simplest form of compass.

The fact that one end of the compass needle always follows a magnet, leads to one of the fundamental laws of magnetism and electricity. It is simply that the north pole of a magnet attracts the south pole of another magnet and repels the north pole. In other words, unlike poles are attracted and like poles are repelled. If you have a number of bar magnets, you can perform several interesting experiments illustrating this point. You will find, for instance, that if you place two magnets with opposite poles next to each other, they will act as a single magnet; that is to say, they will not attract a needle or other steel object at the centre. You can verify this by repeating the experiment with the iron filings (Fig. 3). Now if you place the

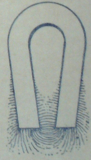


Fig. 2. Lines of force.

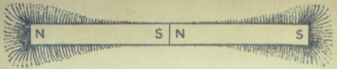


FIG. 3. LINES OF FORCE.

magnets with like poles together, so that there are two north poles in the centre and a south pole at either end, you will find that they attract at the centre equally well as at the ends (Fig. 4).

Here is a more graphical experiment (Fig. 5). Hang a needle from the north pole of a magnet and then place another magnet with its south pole on top of the south pole of the first magnet. The needle will remain suspended, but if you push the magnets slowly together, sliding one across the other, there will come a time when the south pole of one will meet the north pole of the other and the needle will suddenly fall away.

If you could divide a magnet, you would find that it resembles some worms, in that however you divide it, each part always grows a new head and tail. Try the experiment by cutting a thin bar magnet in two with a fine saw or cold chisel. Test the ends of the two smaller bars, and you will find that each has acquired a new pole. Each magnet is complete with north and south pole, and if you were to divide them again, you would find that each of the four pieces still had a north and south pole. So it seems that the magnetic force, although it acts only at the poles, exists throughout the magnet.

"Fishing."—A popular game for children at Christmas

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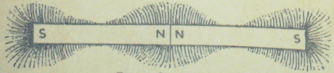
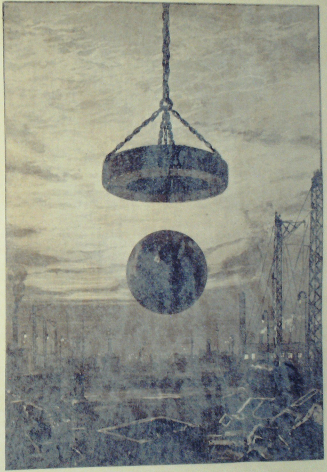


FIG. 4. LINES OF FORCE.



A CRACKER BALL.

Used for breaking bulky scrap metal. When the current is switched off, the magnet releases the ball. Its weight is such that the ball descends with terrific force, reducing the most solid "junk" to fragments.

parties used to be " fishing " with a magnet. The rod and line, on the end of which was a small magnet, was hung over a " pond " in which a number of celluloid fish were swimming. As soon as the line approached a fish, it " bit " and was hauled up. In the nose of each fish, of course, was hidden a piece of steel, which was attracted to the magnet and enabled the fish to be raised. This game is easily constructed at home and is more realistic if very small magnets are concealed in the fish and a needle is used as " bait." The effect will be the same. Another new toy uses magnets to balance the fins of a paper fish so lightly that they sway realistically in the slightest draught.

You may have noticed when experimenting with your magnetic fish that the fish showed a tendency to take up definite positions in the " pond." This was no accident, but in accordance with a definite law, and the experiment is frequently made use of in lecture rooms to demonstrate the construction of atoms. For this purpose floating magnets made by pushing a magnetized needle through a cork are used. The eye of the needle should be made the south pole and the cork should float with the point downwards. Now when you place a number of these magnets in the basin, they will float towards the side. Why ? Because all the south poles are sticking up, and as I have explained, like poles repel each other. Now if you place the north pole of a bar magnet in the middle of the pond (Fig. 6) you will observe them get excited. The corks are torn between two masters. The north pole of the bar magnet says, so to speak, " Come here," while the south poles of the needles say to each other " Go away." The result is a state of equilibrium in which neither force wins—the magnets taking up positions according to their number.

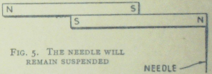


FIG. 5. THE NEEDLE WILL REMAIN SUSPENDED

If there are four magnets, they form a square; if there are seven, one goes to the centre and others form a ring; while if there are eighteen, you will have one in the centre, surrounded by a ring of six which is again surrounded by a ring of eleven. Each number forms a definite pattern and nearly always the same design. Sometimes you may find that five form a square with one in the centre and sometimes a ring, but the exceptions are rare.

This experiment gives a graphic picture of structure by molecules, and if you have glanced into text-books of organic chemistry, you will have recognised the " hexagon ring " and other patterns formed by the magnets.

Making a Compass.—A more permanent and reliable compass than that mentioned on page 19 is very easily constructed. First magnetize a needle by stroking it with a small magnet, always remembering to stroke it the same way in order to keep the poles at opposite ends. Then stick the needle through a cork, so that it is at right angles to the greatest length of the cork. Into the bottom of the cork insert an ordinary pin and into the sides of the cork, just below the needle, fix two match-sticks, with little balls of sealing wax or candle grease at the end.

If this is done correctly—and you may find some notes on the centres of gravity useful here—you will see that the pin may be placed in one of the little holes at the top of a bead and the whole apparatus properly balanced. It may be protected from the vibrations of the air by placing it in a glass-covered shallow box, one of the boxes used by coin or butterfly collectors is excellent, or a glass casserole such as is now to be found in almost every house can be employed. The needle will swing to the magnetic north, and if you hold a magnet in your hand, you can make the needle swing hither and thither.

" Question and Answer " Apparatus.—The compass can also be used to make an ingenious piece of apparatus which will give a good deal of amusement at parties. The apparatus consists of a hand pointer that obediently answers any question chosen by the onlookers.

To construct this instrument, begin with the hand or arrow (Fig. 7). Cut the shape out of paper or cardboard and fix it to the end of a compass needle which is mounted in the bottom of a shallow box. Next prepare two circular pieces of cardboard, divide one of them into sections and write a number of questions, one in each section. You can see a similar idea embodied in the fortune-telling machines to be found on almost every railway platform. Place a small magnet in the middle of the other card and paste the two cards back to back, so that the magnet is held in position, lying along the diameter of the circle. Now prepare a blank " answer card " A; that is to say, a piece of cardboard with a circular hole slightly larger than your question card Q in the middle, and divided up into segments, in which the answers will be written. The questions and answers you choose may be of any kind. You can have scientific, historical, humorous or " fortune-telling " questions. A novel idea is to have a number of examination queries and to make the answers popular " howlers."

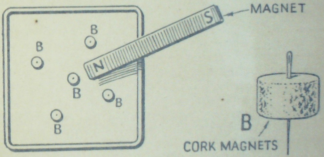


Fig. 6. The corks are torn between two masters.

If you place your question card on the cardboard covering

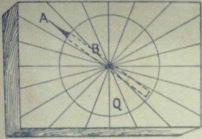


FIG. 7. QUESTION AND ANSWER APPARATUS.

the compass B, the hand will move round, because the south pole of the magnet attracts the north pole of the compass. It will eventually come to rest, and a little experiment will show you in which segment to write the answer in order for it to be correct when the question card is laid down with the compass pointing to the reply. You, of course, are the only person aware of the concealed magnet, and you may find it helpful to mark the position of the magnet with a tiny point, so that you cannot make a mistake in laying down each question card. I am not going to give all the details for the construction of this simple amusement, because it is more enjoyable to work them out for yourself. You can design the instrument as you think best, taking care, if you wish to deceive your friends, to hide the working parts and not to use steel in the construction.

ELECTRICITY

The Simple Electro-magnet.—Electricity and magnetism are very closely connected, and you can prove this for yourself by performing one or two simple experiments. First, take a piece of soft iron and bend it into the shape of a U (Fig. 8). Wind fine insulated wire round and round the arms in opposite directions. To make sure that you are winding it correctly, place the middle of the wire in a straight line on the table. Lay the magnet over it, so that the wire is just below the bend, then take the right-hand end and wind it over from right to left and the left-

hand wire and wind it from left to right. Finally secure the ends of the wire and connect them up with the terminals of a battery or accumulator—a flash-light battery will serve very well. If you now bring a piece of steel or iron near the ends of the iron U, you will find that the steel is strongly attracted, just as it would be to a magnet. You have, of course, constructed a very simple electro-magnet, turning the power of electricity into direct magnetism. Now disconnect the battery and take a horseshoe magnet, bringing it near the wire and rotating it so that opposite poles come near the wire alternately. You will find that an electric current is generated in the wire—you can detect this by means of a galvanometer or by one of the other methods I shall describe later. In this case you have used the principle of the dynamo, for these two simple experiments were performed by Faraday, who virtually founded the science of electricity and gave us the dynamo, without which we should not have electric lighting and electric trains and trams. There is, therefore, a very intimate connection indeed between electricity and magnetism.

Friction.—You have now seen one way of "making" an electric current, or, more properly, of "setting it into motion." There are many others, some of them very simple. The easiest is to charge a suitable body by means of friction. Take a stick of sealing wax or a vulcanite ruler and, after drying it thoroughly, rub it briskly with a warm, dry glove or cloth. Hold the sealing wax or vulcanite over some small pieces of paper and they will fly about, because they are attracted by the charge of electricity. If

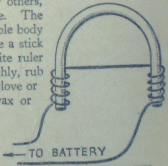


FIG. 8. SIMPLE ELECTRO-MAGNET.

you hold the charged sealing wax over a friend's head, you will find that the hairs stand on end and follow the charged rod as you move it.

All sorts of objects can be induced to take an electrical charge by friction. The most suitable are a glass rod, vulcanite, brown paper, combs and sealing wax. Brown paper will produce electricity in considerable quantities.

Take a large sheet of brown paper, preferably new, and fold it into a strip about a yard long and three or four inches wide. Dry it most thoroughly in front of the fire or in an oven. Then, taking one end in your right hand, draw the paper strip rapidly under your left arm, pressing your arm to your side, so as to get the maximum amount of friction. Do this three or four times, and then place a key or similar object in the middle of the paper. Anyone who touches the key should be able to draw a spark from it. The paper can always be recharged by drawing it under the arm again and with good conditions—a dry atmosphere and dry materials—you can make a spark an inch in length. It is usually cloud friction which eventually causes the lightning flash.

Conductors and Insulators.—It is essential to have dry materials and, if possible, a dry atmosphere, because water which is not quite pure is an excellent conductor of electricity, and any dampness would dissipate your charge before you could use it. Electricity does not travel equally well through all materials. Those which carry it easily—that is without exhausting its energy in heat, such as copper, are called conductors, while those that carry it badly, such as rubber, glass and silk, are called insulators. You will find a number of cheap, strong tumblers very useful for performing electrical experiments at home.

Paperhanging by Electricity.—Electricity simplifies the problems of paperhanging! Dry a sheet of paper, place it against the wall on a dry day, and rub it vigorously one way with a dry cloth or brush it with a clothes brush. The

paper will take up a charge of electricity and will stick to the wall. In the same way, small pieces of paper can be made to stick on your forehead or cheeks.

An Obedient Pointer in a Tumbler.—A tumbler is easily charged with electricity by being rubbed with a dry cloth. When it has been rubbed, it will attract small scraps of paper, cork dust, feathers and hairs. You can make an "obedient pointer" (Fig. 9) with a tumbler and a small arrow cut from paper. The arrow should be cut out of thin paper, should have a small cross-piece in the middle and should be creased down the centre so that it will balance on the point of a needle. Insert the other end of the needle in the top of a cork, and then invert a tumbler over the whole.

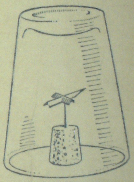


Fig. 9. An obedient pointer.

The problem is to make the arrow turn in any desired direction without touching it or moving the tumbler. It is quite simple. Suppose you are asked to make the arrow turn towards you. Rub the tumbler on the side nearest to you with a dry cloth and in a few seconds the arrow will swing round. The arrow always swings towards the part of the tumbler which has been electrified, because it is attracted by the charge of electricity.

The Electrified Pipe.—Here is another experiment. Balance a clay pipe on the edge of a tumbler in such a manner that it may oscillate freely. The problem now is to make the pipe fall without touching it, blowing upon it, agitating the air, or moving the table.

Take another glass, similar to that which supports the pipe, and rub it rapidly on the sleeve of your coat. The glass will be electrified by the friction, and when you have rubbed it well, bring it close to the pipe, but without touching the latter. The pipe will turn after the glass, and follow it till it falls from its support.

Shadow Painting on Glass.—If you take a plate of glass, clean and dry it, place it across two supports so that it forms a bridge and then rub it, you will find that cork dust placed underneath it flies up. This can be made the basis of an interesting deception. On the lower surface of a glass plate paint the "shadow" of anything you may fancy—a dancer, a dog or a house. Your "paint" must be glycerine, which is colourless and, once applied to the glass, invisible. If you now place the glass on the supports and rub it, the cork dust will be attracted as before. But as soon as you stop rubbing, the attraction will stop, and the cork, except where it has been stuck by the glycerine, will fall back on to the table. The outline you painted will be clearly marked out and can be projected on to a screen by means of a candle.

The Deceptive Dice.—Another amusing deception which puzzles onlookers, until the principles are explained to them, requires the construction of three or four very light dice. These can be cut out of pith and marked with numbers in ink. Place these dice under your glass plate, which should be supported by a book at each end, or better still, lay the glass over a shallow coin collector's box containing the dice, and rub the glass with a dry woollen cloth. The dice will then jump up and stick to the glass. Ask a friend to count the number of pips and give you the total. When he has done this, tell him you are going to verify his statement. In a few moments, you will find that the sum of the pips is not what he stated, and you ask him to count again. He does so, and finds he is wrong, giving you a new total. When he counts yet again in a few minutes, he will find he is wrong, and then it is only fair to him to explain that electricity and not bad arithmetic is responsible for his mistakes.

[*Keystone.*

A photo-micrograph of a young beetle projected on to a screen.

By courtesy of] [*Westinghouse Electric.*

A powerful photo-micrograph apparatus capable of magnification of more than 1,000 diameters.

What has happened is this. The dice are attracted by the electric charge in the glass, but gradually the surfaces clinging to the glass lose their power, and the sides of the dice fall away from the glass, but the dice remain hanging by an edge. Then the glass attracts the adjacent surface, and the dice are pulled up again on to another side. This continues for some time, until the charge is exhausted, the dice turning first on to their corners and then over on to a new side.

Positive and Negative Electricity.—We speak of two kinds of electricity, negative and positive. As with magnetism, we find that like poles or charges repel each other, while unlike poles or charges attract each other. Thus negative attracts positive and repels negative.

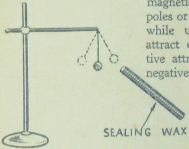


FIG. 10. THE BALL SWINGS OUT TOWARDS THE SEALING WAX.

A simple demonstration of this can be given by the following experiment. Hang a little pith ball from a support like a pendulum (Fig. 10). Next charge a piece of sealing wax by rubbing, and then hold it near the pith ball. The ball swings out towards the sealing wax because it is attracted. If you then hold a glass rod towards the pith ball, it is again attracted, but almost immediately repelled, so that it swings away. The explanation is that when the sealing wax was applied to the pith ball, the ball absorbed some of its negative electricity. Thus it was attracted to the induced positive charge in the glass rod, but almost immediately absorbed some of the positive charge and thus was repelled. If you again apply the sealing wax, you will find that the ball is attracted and repelled in the same way

The Mysterious Boxers.—On the same principle is based the construction of the "Mysterious Boxers" (Fig. 11). Out of very light card cut the figures of two boxers, with arms raised in front of them. Over one side paste some silver paper such as is found in chocolate and cigarette boxes—this makes the surface a conductor. Suspend one of the boxers on a thread from a bracket fixed to a board, and a very short distance away fix the other boxer by one foot to the board, using sealing wax, so that he is insulated. Now connect him to a source of electricity by means of a wire going to his waist and brought into contact with the silvered surface. If you put a small charge of electricity into the fixed boxer, his opponent swings violently at him. After a few moments he apparently steps back and then again lunges forward. And so he will continue, as long as you supply electricity.

The explanation is, of course, that the fixed boxer receives a positive charge of electricity and violently attracts the swinging boxer. After a moment or two of "clinching," the other boxer takes up some of the positive charge, and since positive repels positive, he swings back. Presently the positive charge is dispersed, and he once more swings forward, and so he continues.

Any source of electricity will serve. Brown paper that has been charged may have the connecting wire twisted to one end, or a glass cylindrical lampshade, fitted with a cork through which a nail passes, may be used. The wire should be connected to the nail, and the shade should be rubbed. In this way it will supply indefinitely a small but sufficient charge of electricity as long as the friction is applied.

The Dripping Tap.—The fact that opposite charges attract one another can be demonstrated in a number of other ways. One of the most striking is to bring near a dripping water tap a comb or piece of brown paper that has been charged by friction. You will, if you look closely,

immediately notice that all the drops join together to form a continuous stream.

The accepted explanation of this phenomenon is that the comb or brown paper has an excess of electrons and is, therefore, negatively charged. These electrons repel the negatively charged electrons in the water drops to the farthest side, so that one side of a drop is negatively charged and the nearest side of the next drop is positively charged. Now since negative attracts positive, the drops coagulate. All this happens, of course, so quickly that it appears to be instantaneous. This principle of pressure variation has been used in practice to clear a windscreen or to disperse a small quantity of fog.

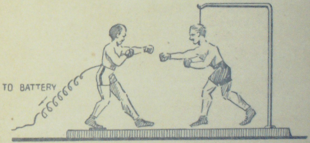


FIG. 11. THE MYSTERIOUS BOXERS.

The Swing.—A fountain pen, being made of vulcanite, is a useful source of small quantities of electricity. It can be charged by being dried thoroughly with a warm cloth and then rubbed vigorously. The charge is sufficient to work a small swing or to make a paper figure of a man walk after the pen. The swing is easily constructed out of a match-stick, after the head has been removed. Fix a light paper figure on the swing, and support it by threads. Then hold the charged fountain pen towards it. The figure is attracted according to the laws. Remove the pen and the swing goes back, and if you hold the pen towards it again as it swings forward with the momentum, it will once more be attracted. A more vigorous swing can be achieved with two fountain pens, one being held at each end of the swing.

The Electrophorus.—One of the earliest pieces of apparatus used for storing charges of electricity was called by our grandfathers an electrophorus, and since it provides an easy way of securing charges of electricity for a variety of experiments, I will describe one or two of the simpler types.

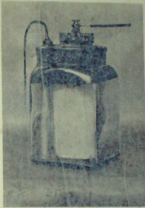
Place a lacquered tray on four tumblers so that it is insulated from the table, the tumblers at the same time acting as supporting legs (Fig. 12). Next cut out of brown paper, preferably new so that it is not creased or broken, a piece to fit the inside of the tray exactly. Warm the paper thoroughly in order that it is quite dry. Now on the upper surface gum two small pieces of paper to serve as handles, and lay the paper in the tray and charge it with electricity, either by rubbing it or by stroking it with a dry brush. Be sure always to rub or brush in the same direction, that is, down its greatest length. Place the paper in the tray and ask a friend to put his finger on the corner of the tray. Then gently lift up the paper, and a spark will fly between the tray and your friend's finger. A single charge should, if conditions are good, be sufficient to provide half a dozen sparks, the brown paper being raised each time. This electrophorus will provide charges for a number of simple experiments and will act as a good substitute, in some of those tricks already described, for simple brown paper or sealing wax.

Another electrophorus can be made as follows. First you require a piece of thin ebonite about a foot long and six inches wide. This should not be hard to obtain from any wireless shop, but make sure you get ebonite and not a composition substitute. Next cut a piece of tin about three inches long and two wide and fix it to the centre

By courtesy of]

THE DRY CELL.

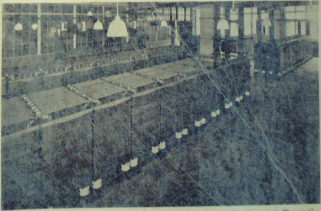
Here the positive element, zinc, takes the form of the outside container. This is covered by a cardboard case to insulate it. In the centre of the container is the carbon stick or plate. Packed round this is first the "black paste" and then the "white paste."



[Gent & Co. Ltd.

THE LECLANCHE CELL.

This cell has a solution of sal ammoniac as the exciting fluid. A zinc stick forms one plate, whilst the other plate is of carbon.



By courtesy of] [The Automatic Electric Co.

BATTERIES FOR AN AUTOMATIC TELEPHONE EXCHANGE.

Some of the 50-volt batteries weigh over 100 tons, and supply enough energy to light nearly 1,000 houses.

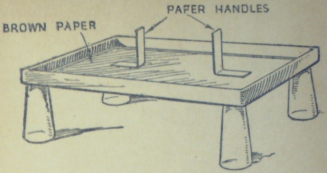


Fig. 12. The electrophorus.

of the ebonite. Your apparatus is now ready. Place it on a dry wooden table and charge it by rubbing with a cloth. Then raise the ebonite and a spark may be drawn from the tin. You should get a spark about half an inch long from your finger, but it will not hurt, and will give only a faint pricking sensation, for the actual current is exceedingly small. If you have the patience and ingenuity to construct a number of small light wooden dolls and place them on the tin, they will behave very amusingly when the ebonite is raised. A doll's hair, if it is long, will stand on end, others with jointed limbs will throw them wildly about, while yet others may be jerked right off the table.

The Leyden Jar.—For many years the almost universal general source of electricity in the laboratory was the Leyden jar, which is capable of storing a considerable charge. In its very simplest form a Leyden jar is easily constructed at home. The more elaborate pieces of apparatus, used for laboratory experiments, are hardly worth the trouble of making, for they can be purchased quite cheaply.

To construct a simple Leyden jar you need some lead shot, a glass tumbler and a silver spoon (Fig. 13). Half fill the tumbler with lead shot and in the middle place the spoon so that it stands upright. Your Leyden jar is complete and may be charged with one of the electrophorus sets already described. Place the handle of the spoon against the corner of the tray or the piece of tin in place of your finger and, instead of sparking, the charge will enter the Leyden jar and be stored for use when required. It may be stored almost indefinitely or "discharged" by placing the finger against the spoon, when a spark will pass across the gap. The disadvantage of the Leyden jar is that the whole of the charge is exhausted at once, and if you are giving a number of demonstrations you should have several jars charged and ready beforehand. In damp air the charge is only transient, while an outer coat of tinfoil halfway up the jar will render it suitable for a greater charge when employed with modern apparatus.

The Galvanometer.—How can we detect the presence of an electric current in a wire? There are a number of ways, one of which is by using the galvanometer, a sensitive needle which swings when there is the slightest variation in the current. By means of reflecting mirrors which magnify the movement of the needle, it is possible to measure the minutest changes in the amount of current passing through a wire.

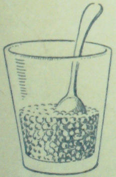


Fig. 13. The Leyden jar.

The Electroscope.—A simpler instrument to use at home, with so-called static charges, is the electroscope (Fig. 14). This consists of two sheets of gold leaf A suspended from a terminal. An inch from the gold leaves are two metal points B which act as "dischargers." If you bring a positively charged body near the terminal, the gold leaves bend outwards until they touch the metal points, when they are discharged and collapse. If you introduce a negative charge, they will bend together, straightening out when you remove the body. The explanation will be plain if the law concerning the attraction of opposite poles is remembered. The electroscope is usually enclosed in a glass jar in order to protect the delicate gold leaves from draughts and damp.

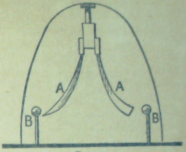


Fig. 14.
The electroscope.

The principle of the electroscope can be shown very simply. Fix a metal rod horizontally on a stand, insulating it with a piece of good rubber or glass. From either end of the rod hang a small cork or pith ball by two inches of very fine copper wire. The two balls are, obviously, connected by the wires and rod to each other. If a piece of sealing wax which has been positively electrified is now brought near to one of the balls, the ball will swing out, while the positive charge, travelling along the wires and rod, will make the other ball also swing out. As soon as the wax is removed, the balls will again hang vertically. These balls behave in exactly the same way as the gold leaves of an electroscope.

A very simple form of the gold leaf electroscope can be made at home, and silver paper will do instead of gold leaf, although it is heavier and not so sensitive. Bend a piece of iron wire twice at right angles so as to form a rough hook. Catch this on the edge of a tumbler and keep it in position with a metal dish or the lid of a tin. Make sure that the vertical part of the wire does not touch the glass, and across the bottom horizontal section hang a piece of doubled

NAWAB SALAR JUNG BAHADUR

silver or gold paper. Your electroscope is now complete and will respond to charged sealing wax and other bodies as I have already described.

With this instrument you can test the charges in the various articles you have used for producing electricity. Test, for instance, the charge in sealing wax, in a glass rod, in a piece of brown paper, in the woollen glove used to electrify them and in the clothes brush. You will discover at least one interesting fact, namely, that whenever two bodies are rubbed together to produce electricity by friction, one of them is positively charged and the other negatively charged.

When you come to carry out some of the experiments with soap bubbles, which I shall describe later, you will find that the bubbles can be electrified. If you make a number of strong bubbles and let them rest on the table, you will be able to pull them about with charged sealing wax or brown paper. You will find that the bubbles will become elongated into the shape of an egg. After lifting a bubble by means of a piece of sealing wax, bring it into contact with your electroscope and see if you can detect a charge.

Accumulators and Batteries.—In common use, there are three principal sources of electricity. The most important is the dynamo, for this actually produces or sets into motion the electricity which is relayed through wires to thousands of homes and factories. Electricity from a dynamo can be stored in an accumulator to be used as required. This accumulator is the second convenient source. The third is a primary battery, which " produces " electricity by chemical action. These are commonly used for door bells and in other cases where only a small current is required for a short time.

The earliest battery or " pile " was produced as a result of an academic dispute between two learned scientists about frogs' legs. Galvani, an experimenter of the 18th century, happened to notice by accident that when frogs' legs were brought into contact with metals they twitched—the discovery was made while he was cutting up frogs for some brew recommended for his wife by the local physician! After various experiments, Galvani decided that the legs generated the then little understood force of electricity. All Europe became excited over his discovery, and I believe that fashionable parties were given to demonstrate the twitching of limbs which, it was believed, would eventually show us how to restore the dead to life!

Then came the scientist Volta, whose name is commemorated in the Volt, with, literally, rather a damper. He said: " Your frogs' legs are nothing but a bit of wet rag. Give me two different metals and a wet rag and I will produce electricity." Thus was invented the Voltaic pile, the first " battery." It consisted of alternate discs of moistened copper and zinc.

The Dry Battery.—A very simple Voltaic pile can be constructed out of gold and silver paper. Take two sheets of gold leaf and paste them together. Next cut out discs about one and a half inches in diameter. Do the same with sheets of silver paper. Now get a glass tube—a cylindrical oil lamp shade will do—into which the discs will fit and press them in, making sure that gold and silver alternate and ending with gold at one end and silver at the other. Fit corks to the shade and pass through them thin copper wires, making a good contact with the outermost silver or gold disc. You will find a small current is generated and this may be tested with the electroscope or galvanometer. This is called a " dry " pile and will generate electricity for a considerable time.

The Wet Battery.—After his pile, Volta proceeded to make a " couronne de tasses," which was really a " wet " battery. Instead of discs, he used bent bars of copper and zinc, arranging them in glass jars containing water so that each jar contained one bar of copper and one of zinc.

From the copper and zinc extremities he was able to draw a substantial current. You may repeat this experiment yourself, bending the strips of copper into the shape of a U with square corners, and using jam jars. The current will be improved if water which contains a small quantity of sulphuric acid is used. Really pure water does not conduct electricity, and this is due to a cause similar to the one that prevents chemically dry coal from burning even when made red-hot.

A very interesting story is told of the scientist Wollaston. It is said that on meeting a friend in the street one day, he proceeded to make a microscopic pile, or battery, out of a thimble. This sounds almost incredible, but the description of how he went to work is worth giving, as there is no doubt that the pile will work, and those who like working with minute quantities may be interested in the Wollaston experiment. The part that is hard to believe is that even an inventor should have been carrying the necessary ingredients in his pocket—especially a thimble!

Wollaston, it is said, produced a copper thimble, knocked out the bottom and flattened it with a stone. He then placed a small strip of zinc between the two copper sides, insulating it with a little sealing wax. This apparatus he placed in a glass container filled with water acidulated with a little sulphuric acid. Finally he wound a piece of very fine platinum wire round the copper and zinc. The electricity generated by the pile made the platinum wire red-hot, and in some cases this might even bring about its fusion. The length of wire between the copper and zinc was only one-thirtieth of an inch, and it is said that a tinder could be lighted at the red-hot wire.

Batteries of various kinds are so cheap that it is hardly worth the trouble of attempting to construct them, except as a matter of interest. It must be remembered, however, when buying for experimental purposes, that the Leclanché cell, which is generally used for electric door bells, will not give a continuous current for more than five or ten minutes. After that it requires a depolarising rest before it will work again. If accumulators are not easy to obtain and charge, a bi-chromate cell is well suited for all experimental purposes.

"Sparking" and "Shorting."—If you bring the wires connected to the two terminals of an accumulator or powerful battery together, you get a spark. This, of course, is in accordance with the law relating to the attraction of opposite charges. The electricity is so attracted that it leaps across the intervening air. The spark is only yellowish-white in air—in other gases a number of different colours are produced, while in a vacuum it is pure white. Very considerable voltage or pressure is needed to bridge the smallest gap of air. This "jumping" must not be confused with the flowing of current across a space made conductive by the vapourising of the two electrodes.

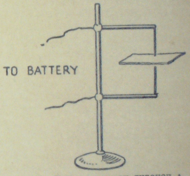


FIG. 15. PASSING A SPARK THROUGH A PIECE OF PAPER.

An electric spark can be made to pass through a sheet of paper or even a plate of glass. For this experiment you should support two steel needles, with their points very nearly touching (Fig. 15). Place a piece of paper between them and then connect up with a battery of Leyden jars. Immediately the spark will pass through the paper. The same procedure should be tried with a glass plate, although in this case it is advisable to put a spot of oil on the glass beneath the needle; this is to prevent the charge being dispersed over the surface. It is never advisable to "spark" or "short" an accumulator, for not only will the charge be prematurely exhausted, but the plates of the accumulator may be permanently damaged.

Electro-magnets.—The construction of simple electro-magnets has been explained when dealing with the connection between magnetism and electricity. More powerful electro-magnets are more difficult to make, and are, perhaps, best bought. But you can, with a "core" of soft iron, the right kind of wire, and a good deal of patience, wind an electro-magnet for yourself.

A Model Crane.—With a small electro-magnet—one removed from a door bell will serve—you can make a model crane. Suspend your electro-magnet at the end of two fine copper wires which will wind easily over a reel, and connect them to a switch and battery. With this simple crane you will be able to raise small metallic objects, including the lid of a "tin," for although tin is not attracted to a magnet, the inner core is of iron.

In the steel and metal industries electro-magnets are used for lifting bars of metal and scrap. The magnet is lowered on to the load, the current is switched on and the magnet raised with the steel or metal held to it by attraction. When the magnet has been moved to the desired position, it is lowered, the current is switched off and the load dropped. Electro-magnets are also used for smashing scrap iron. A heavy metallic ball is raised by means of a magnet, and when it is poised over the scrap, the current is switched off. The ball falls with great force and in due course is picked up again for the process to be repeated.

Concealed electro-magnets can be made the basis of many amusing demonstrations, and I have no doubt that they have been extensively used by charlatans and fortune-tellers for deceiving the gullible.

The Obedient Doll.—One of the easiest working models

to construct with an electro-magnet is an "obedient doll" (Fig. 16). Later on I shall describe a similar obedient doll worked by air pressure, but in this case the operator does not, apparently, touch the doll or the containing bottle.

The doll seemingly obeys the commands of anyone, rising, falling and dancing to order. For the construction of this "mystery" all you require is a small celluloid doll such as can be bought for a few pence, an electro-magnet with a battery and switch on the end of a length of flex. Weight the doll at the feet so that it floats upright in a jar of water with its head just below the surface. Clamp on a lid and seal it—just to show there is no deception! A very convenient jar for this purpose is one of those with a metal lid, in which pickles or jam are packed. Next fix your electro-magnet under the middle of the table and a fraction of an inch from the underside of the wood. Carry the wires down the leg to a battery and switch on the end of a couple of yards of flex. The best switch for this and similar mysteries is a bell-push or a pear-shaped push which can easily be concealed in the hand or pocket. Now give the order to sink and at the same time press the switch so that a current

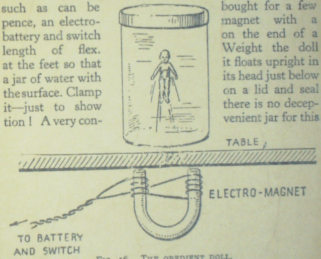


Fig. 16. The obedient doll.

passes to the electro-magnet. The force will be exerted through the wood, the bottom of the jar and the water, while the metallic weight at the bottom of the doll will be attracted down to the bottom. Now command it to rise and at the same time release the switch so that the current is cut off. The doll will rise of its own buoyancy to the top, or it can be made to dance by switching the current on and off very rapidly, but this takes a little practice. If someone else gives the orders, you have merely to synchronize the working of the switch in your hand to see that they are carried out. The most difficult part of this experiment, when performed in a drawing-room, is to conceal the flex, but since our first object is not conjuring, this is, perhaps, not very important.

The Tame Goldfish.—A similar experiment can be performed with a jar of "tame goldfish." The goldfish are of celluloid or metal, and in either case must contain some magnetic substance. The electro-magnet and switch are arranged as before, and the fish can be made to swim round, sink and rise. By fixing a "commutator" such as I shall describe when we come to the telegraph, you can make the current, and consequently the fish, reverse to order.

Many interesting and amusing experiments of a more advanced nature can be performed with the aid of electro-magnets. It is possible, for instance, to fry eggs on ice, to suspend a ring of metal in mid-air, or to light an electric lamp by placing it in your ear! When seen on the stage, these experiments seem almost supernatural, but an understanding of how they are done shows that the performers merely make use of the known laws of electricity for spectacular purposes.

Frying Eggs on Ice.—All these experiments make use of electro-magnets whose size and construction depend upon the conditions. Most of them call for a magnet very considerably more powerful than that used in the ordinary door bell. In order to fry eggs on ice, for instance, a fairly powerful electro-magnet with an iron core is placed under the table in the way I have described. The lump of ice, which may be as much as six inches thick, is placed above the magnet and a copper pan, into which the eggs have been emptied, is laid on the ice. The current is switched on, without, of course, the knowledge of the onlookers, and in a very short space of time the eggs begin to sizzle and fry!

The explanation is that the copper pan becomes, in the language of electricity, the secondary circuit of an alternating current transformer of which the electro-magnet possesses the core and primary winding. In simpler language, we may take it that the current is induced through the ice into the pan, where Joule's law, showing the connection between heat and energy, accounts for the evolution of heat in the pan. The "lines of force" travel through the ice with comparatively little loss of energy. An important point is that the gap between the ice and the electro-magnet should be as small as possible, or waste of power will result, and further, there should be no conducting material of any kind near to absorb the energy of the magnet. If you can use a special table for this experiment, it is a good plan to cut a small hole in the middle of the wood so that the magnet and ice are almost touching. This electric induction scheme is the basis of many large commercial furnaces.

Lighting a Lamp from the Ear.—Similar apparatus is used for lighting a lamp from the ear. It is necessary to prepare the lamp by connecting it up to a small coil of about 1,400 to 1,500 turns. This can be concealed in a small baseboard. When the lamp is brought within eight or nine inches of the electro-magnet under the table, it will light up. In performing this experiment care should be taken not to bring the lamp too near the electro-magnet or the wires will burn out. For stage purposes, it is more spectacular, of course, to place the lamp against the side of your head and then to bend down over the table, when the lamp will light up by "induction."

As yet, the distance over which a lamp can be lit by this method is exceedingly small, and inventors are busy trying to discover a more effective and less wasteful method that will enable us to light our street lamps and homes without going to the trouble and expense of connecting them up with wires. The most hopeful method seems to be the transformation of electrical energy into ætherial energy (wireless waves) which are in turn reconverted into more ordinary conditions of electrical energy at the receiving end. In theory this is fairly easy, but as yet it has not been performed at a distance of more than a few yards, and even then only with great loss of energy. A number of remarkable experiments can be made by means of a Tesla coil, but this apparatus needs considerable power and is not always safe in the hands of an amateur.

"Levitation."—The electro-magnet can also be used for a "levitation" act in which a metal ring is suspended in mid-air (Fig. 17). There is really no deception about this—the metal ring really does hang in middle-air without any visible support! An aluminium ring is best for this experiment and it should be secured to the table with a thin piece of cotton—this can be explained, if you are bent on deception, by saying that it is necessary to prevent the ring from flying to the ceiling! When the electric current is switched on in the magnet, the aluminium ring can be raised as far as the cotton will permit, and will remain suspended when your hand is removed. Actually, of course, the explanation is that it is held suspended in the magnetic field of the electro-magnet—you saw the nature of a magnetic field when you performed the experiment with the floating magnets which made patterns upon a bowl of water.

Electric Lighting.—If you connect up the opposite poles

of a battery with a fine iron wire, you will find that the wire becomes very hot, indeed, it may become white-hot. Here you have a simple form of electric light—actually, of course, many years of research and tens of thousands of pounds went to discover the ideal wire or "filament." This experiment of bringing the opposite poles together should never be tried with a powerful current—such as that used in houses, as the energy will be so great that you may seriously hurt yourself and will certainly blow a fuse. However, with a battery or accumulator of comparatively low pressure you are quite safe.

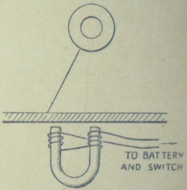


FIG. 17. LEVITATION ACT IN WHICH A METAL RING IS SUSPENDED IN MID-AIR.

Fuses.—Many people are ignorant of the purpose of a fuse and regard it merely as a nuisance which invariably has to be replaced at some awkward moment. If you take a single strand of the lightest fuse wire—a couple of feet will only cost a penny—and connect it up with the opposite poles of an accumulator which has been recently charged, you will find that the metal rapidly bends and eventually melts, breaking the circuit. This is the function of a fuse. When, for some reason, the current approaches the danger point, the metal, which is usually an alloy of bismuth or cadmium, becomes hot and melts, thus breaking the circuit. It melts at a temperature well below that of ordinary copper wire and therefore provides a safety valve which is the means of saving many fires and accidents. Some fuse wire will melt in ordinary boiling water, and, as a matter of fact, you can have a great deal of amusement by casting a teaspoon out of a fusible alloy. When your unsuspecting visitor begins to stir his tea, the spoon will simply melt and disappear, much to his astonishment. The spoon will be found in a molten state at the bottom of his cup, and I hope you will give him a fresh cup of tea and keep the metal to make another spoon! Similar fusible plugs are used to release water jets, to extinguish fire, when the temperature rises above a certain safety limit.

The Carbon "Arc."—With a good four-volt accumulator you can make an imitation of an "arc." For many years the carbon arc was the only known means of electric lighting, and a very inconvenient form it was. The lamps gave a prodigious heat, spluttered and required almost as much attention as old-fashioned candles which had to be snuffed. You require two sticks of carbon, which should be supported horizontally with the points a quarter of an inch or less apart. When you pass a current from the accumulator through the carbons, the ends will rapidly become incandescent, giving a momentarily brilliant light and intense heat. The ends burn away rapidly, so that if you wish your experiment to be continuous, you should fix one carbon in such a way that it can be pushed towards the other as they burn away. A small accumulator of low pressure will not provide a proper arc because the heat causes a current to be produced which tends to resist that of the battery. You can make bright sparks, but for real burning a steadying resistance and a pressure of about sixty volts is needed. Do not confuse pressure with current. Large accumulators may be large in capacity and may supply plenty of flowing current. But the high tension battery as used in a radio set may be able to break down a big resistance because its pressure is high with the available current quite small.

Because of the intense white light it gives, the carbon

arc is still used for cinematography, while the heat is very useful in many industrial processes. Indeed, it is still one of the greatest artificial heating agents known to man.

Electrolysis.—If you place under water the bare ends of two wires coming from the terminals of a strong accumulator, you will notice bubbles being formed round them. The effect will be intensified if you add a few drops of acid to the water. With the ingenuity and patience necessary to arrange the apparatus, by an electric current, you can split up water into its main component elements, hydrogen and oxygen—the experiment is called the electrolysis of water. The apparatus is fully described in every textbook of chemistry, but a simple method is to take the insulated wires under the water in a bowl and bring them up into two inverted test-tubes, filled with water, with their mouths just under the surface of the water in the bowl (Fig. 18). Switch on the current, and the gases will collect in the test-tubes. You will notice that far more gas is collected in one tube than in the other—the greater quantity is the hydrogen (H). The hydrogen collects on the negative electrode and is therefore called "electro-negative"; while the oxygen (O) collects on the positive electrode and is called "electro-positive." An electric current will decompose many compounds, but they must be in liquid form, either in solution or melted.

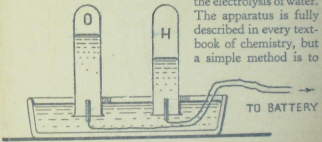


FIG. 18. THE ELECTROLYSIS OF WATER.

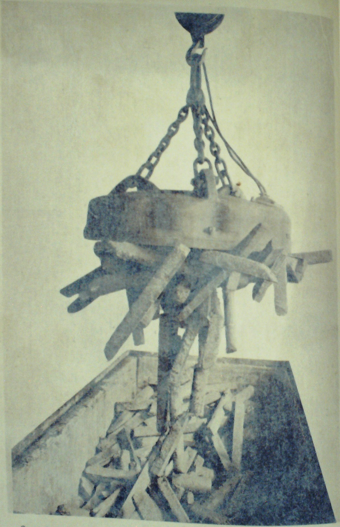
It is used on a large scale for the preparation of a number of substances in common use.

More difficult experiments in electro-chemistry can be performed in the home, if a suitable workshop is available, but in using high voltages, of course, the greatest care should be exercised.

"Carbide."—Perhaps the most interesting of these experiments is the production of calcium carbide, popularly known as "carbide," on a small scale. This compound is produced at the rate of 500,000 tons a year for the production of acetylene gas, not only for lighting, but also for the oxy-acetylene flame used in cutting steel. On a large scale the compound is prepared by heating quick-lime with an excess of coke in an electric furnace. Few amateurs have the use of an electric furnace, but a voltage of between sixty and a hundred is sufficient to produce the compound.

The easiest way of conducting the experiment is to use a graphite crucible and a carbon anode. The carbon should almost touch the bottom of the crucible. When the current is switched on, great heat will be produced, and at this stage the quicklime and crushed carbon or coke should be added. After the resulting mass has cooled, a little can be thrown on to water, when acetylene gas, which can be recognised by its smell, will be evolved.

Pigments.—Many of the pigments used by painters can be made by electrolysis. White lead, for instance, is the basis of most white paints, and it can be produced from lead and sodium carbonate, or washing soda. Dissolve a little potassium chlorate with a little sodium carbonate in water, and pour the solution into a vessel containing two lead electrodes. Carbon di-oxide—the easy preparation of which is described later—should be bubbled through the solution slowly at the same time as the current is switched on, when white lead will appear in heavy clouds. After the conclusion of the experiment, you can, if you wish,



By courtesy of] [*Witton-Kramer Ltd.*

A toy that has become a tool. An electro-magnet unloading pig-iron from a railway truck.

collect the lead carbonate by pouring the liquid through a funnel in which a filter paper has been folded.

A similar apparatus can be used for the production of other colours. Cadmium sulphide is a yellow compound. The changes necessary to produce this material in the same apparatus are simply the substitution of a strip of cadmium for the lead anode and of carbon for the lead cathode. Instead of potassium chlorate and sodium carbonate, use common salt as the electrolyte. The solution should be saturated, that is, incapable of dissolving more salt. In this case hydrogen sulphide and not carbon di-oxide should be passed through the apparatus, when clouds of finely-divided cadmium sulphide of a brilliant yellow colour will appear.

Mercuric Bromide.—Another interesting experiment in electrolysis is the production of mercuric bromide, so that it glows with a brilliant orange light. For this you should place a shallow layer of mercury in a small dish and connect it up to the positive terminal of a battery by insulated wire. On top pour a weak solution of potassium bromide and dip into it a thin foil of platinum connected to the negative terminal of the battery. The "bromide" will be formed on the surface of the mercury and will glow beautifully for several minutes.

Etching on Metal.—Electrolysis is used for etching on steel, for silver and nickel plating, and altogether is one of the most useful processes known to the metal industry. Silverplating can be accomplished at home, but as the apparatus is rather expensive, I will leave enthusiasts who wish to try their hands to study the subjects in one of the many text-books. On the other hand, it is easy for you to etch your name and address on your tools or on any other metallic objects.

First type your name and address on a stencil sheet—sometimes called a mimeograph stencil. It is important that the type should be clean and, of course, the ribbon of the typewriter must be disengaged. If you are at all doubtful, get a professional typist to do it for you, it does not take two minutes. Cut out the lettering, leaving a reasonable margin. Make a saturated solution of copper sulphate. Now take a piece of sheet copper slightly smaller than your stencil and on top of it place a piece of blotting or filter paper. Soak the blotting paper with the copper sulphate solution and lay the stencil over it. Place the tool or piece of steel to be etched on top of the stencil, making sure that it is clean. The current for the etching can be obtained from an ordinary car accumulator, the negative wire being brought into contact with the copper and the positive with the tool or other object to be etched. In about five minutes the name will be found to have been bitten into the tool—and no one will be able to remove it, unless they decide to eat it away with acid!

The explanation of this method is fairly obvious. The stencil being of wax prevents the steel being attacked, except in the gaps cut by the typewriter, while the part played by the copper sulphate is that of an electrolyte.

Copperplating.—Copperplating on steel is a fairly simple process, as long as the steel is clean. If you have a pocket knife you do not value, or if you can borrow one from a friend, you can copperplate it by merely dipping it into a solution of copper sulphate. After a time the copper will be deposited on the steel blade, making it look very pretty, but ruining its cutting qualities. Nickel can be deposited in a similar manner, but the fumes from the liquids used are very troublesome.

Alloys.—Some metals have the curious and interesting property of uniting with other metals to form new metals, which are not chemical compounds and yet are very stable. The commonest of these alloys is brass, to be found in every home. Alloys are becoming more and more numerous and useful every year, as with them we can produce exactly the metal required for a special task, instead of having to make do with the best available. In the ordinary motor car, for instance, some dozen or twenty different alloys are used for different purposes.

Mercury is very peculiar in its affection for other metals. Its alloys are called "amalgams," and the mercury-silver amalgam is familiar to everyone who has had a tooth stopped! Usually no heat is required to form mercury amalgams. You can use this knowledge to produce an amusing piece of deception.

The Silver Farthing.—Offer to change a friend's farthing into a sixpence merely by wrapping it in your handkerchief. He will rightly disbelieve you, but will probably offer the farthing as it will seem to be a good bargain. In your handkerchief you must have a few globules of mercury and when you have wrapped up the farthing you must rub the mercury over it. After some time you will find the coin has become silvered all over, the mercury sticking to the copper. When you return the farthing, which at a first glance will look like a sixpence, be sure and tell your friend that you have played a trick on him, or he may attempt to pass the sixpence and find himself in trouble!

There is a danger that the mercury will not stick if it cannot get into contact with the metallic copper because of a film of oxide such as is usually found on copper coins. This coating is easily removed by dipping the coin for a minute into a dilute solution of nitric acid.

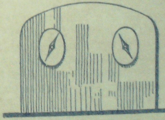


FIG. 19. A HOME-MADE TELEGRAPH.

THE TELEGRAPH AND TELEPHONE

Although modern telegraphic and telephonic apparatus is often extremely complicated, it is possible to understand the basic principles and make miniature pieces of apparatus for communicating from one room to the next. These will be very much like the first telephones and telegraphs which astonished our grandfathers, but they can provide a great deal of amusement.

The first and simplest form of the telegraph is the "needle" type still used in railway signal cabins. In this instrument, use is made of the effect of a changing direction of current upon a compass needle.

If you make a large coil of half a dozen turns of insulated wire and place in the centre a compass needle, you will be able to see the effect of altering the direction of the current. Connect up the ends of the wire with the terminals of a battery and the compass needle will swing into position. It is just as if you had presented the north pole of a magnet. Now reverse the connections, so that the wire which was connected to the positive terminal is connected to the negative terminal. The compass will swing round so that the other end of the needle is pointing to the wire. The effect is the same as if you had turned your bar magnet round and presented the south pole.

A Home-made Telegraph.—For a home-made telegraph (Fig. 19) you need two compass needles to which you attach the indicating pointer by a spindle, supported in an upright position, with the indicator in front and the compass needle behind. Round the compass needle make a coil of wire, as you did in the previous experiment, and carry the ends to a battery and to your sending station. Now if you put the current through this wire in one direction, the needle will take up one position; if you put it through in another direction, it will turn in the opposite direction. These positions enable messages to be transmitted in Morse code, one position standing for a dot and the other for a dash.

In order to change the direction of the current, you can, if you wish, simply hold the wires in your hands

and touch the correct terminals in turn, but usually an instrument called a commutator is used. In its simplest form this consists of four brass upright pieces fixed on a stand on insulating material, two of which support a cylinder of insulating material along which run two brass bands. Thus, when the cylinder is in one position, the bands are side by side and they touch two connections; while when it is in the next position, the brass bands are under the second set of contacts and a connection is made across the other two uprights. By connecting two of the terminals to the telegraph instrument and two to the battery, you have a simple means of changing the direction of the current, simply by turning the cylinder handle.

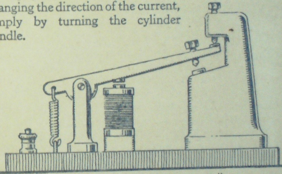


FIG. 20. A MORSE "SOUNDER."

A Morse "Sounder."—This is a quicker and an improved simple form of telegraph instrument and is easier to make (Fig. 20). First obtain a wooden baseboard and on it, towards one end, fix a small electro-magnet—that from a door bell will serve. Now make a wooden arm and support it at one end so that the longer part passes over the magnet. The shorter end has a spring attached to the baseboard so that when the arm is released by the magnet it jumps back into place. The other end of the arm must have a terminal in it, an inch from the end, and at the extreme end another piece of metal. This final piece of metal, when the magnet is not pulling, is in touch with an overhanging support.

If you work this bar up and down with your finger, just as if by the magnet and spring, you will find that two distinct sounds are made—a "click" when it comes down and a broader "clack" when it goes up. A dot is represented by a quick "click," a dash by a longer "clack." Now connect up your magnet with a battery and by taking one wire on and off a terminal of the battery, you will produce a series of "clicks" and "clacks." For convenience, this "sounding" is performed by a commutating instrument fitted with a convenient handle.

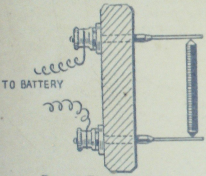


FIG. 21. THE TELEPHONE.

The plain sounder is simpler to make. All you require is a metal arm, which when pressed down connects up the battery circuit—it is really a switch that can be pressed off and on very rapidly by a key. When you press this key down for an instant, you will get a dot from your instrument; when you press it down for a longer time, you get a dash. The interval between letters is, of course, slightly longer. Expert operators can use the instrument very fast, and many devices have been invented for making tapping more rapid.

Codes, abbreviations and other mechanical devices enable the time taken in transmitting a message to be greatly reduced and, of course, in actual practice, several messages are "duplicated" over the same wire. Further,

messages are automatically taken down by machines that punch holes in a long paper tape.

It is a good plan to memorize the Morse code, and so I give it here.

a . -   b - . . .   c - . - .   d - . .   e .   f . . - .   g - - .
h . . . .   i . .   j . - - -   k - . -   l . - . .   m - -   n - .

o - - -   p . - - .   q - - . -   r . - .   s . . .   t -   u . . -
v . . . -   w . - -   x - . . -   y - . - -   z - - . .

Automatic Message-taker.—It is not hard to make an automatic message-taker for your home telegraph, although it will be difficult to construct one that will work in your absence. The easiest way is to substitute a pencil for a terminal at the end of your tapper, and to pass a paper tape under it at a regular speed. Each time the tapper descends in response to an impulse, a mark will be made on the tape, which you will afterwards be able to read. The easiest way in which to draw the paper is by gravity—attach a weight to it, and the paper can be made to descend at a reasonably regular rate past a spring check. If you are ingenious, however, you may be able to work the tape by clockwork or from your gramophone.

The Telephone.—The telephone depends on the varying resistance provided by a microphone to the passage of an electrical current and to the turning of these vibrations into sound by means of a diaphragm. A very simple microphone may be made with two thin blocks of carbon and a carbon pencil (Fig. 21). Mount the carbons, the length of the pencil apart, so that the pencil is just held in place. Now the slightest pressure on the carbon blocks will tighten the grip on the pencil, and although it may be imperceptible to the eye, it will be sufficient to vary the resistance. The carbons should have attached to them two terminals which, of course, pass to the battery and earpiece circuit. In making your connections, pass one wire from the microphone to the battery and thence to the receiver, and take the other wire direct to the other terminal of the receiver. With an instrument such as this and a pair of headphones you will be able to hear a fly walk across your microphone and the proverbial pin dropping will sound quite a crash! This is, of course, a very elementary microphone, but it can provide considerable entertainment.

EXPERIMENTS WITH HEAT

CHAPTER II

EXPERIMENTS WITH HEAT

HEAT is a form of energy which travels through the æther as waves or oscillations in much the same way as signals broadcast by wireless waves. We could, with suitable apparatus, transmit sound by heat waves, turning the sound waves into heat waves at the transmitting end and converting them back into sound waves at the receiver. There would, however, be little point in this experiment, for heat waves do not travel great distances without considerable loss of energy.

Many experiments can be performed to show that heat is a form of energy. We all know that wheel axles have to be oiled to keep them cool, and that the barrel of a gun soon becomes red hot if one shot after another is fired. Even the comparatively small amount of heat that reaches us from the sun may be set to work. You have probably noticed a radiometer in the window of an optician's shop. This instrument, which is very simple in construction, has nothing to do with "radio," but takes its name from the fact that it is worked by the radiations from the sun. Nor, is it, as many people imagine, worked by light. We have not yet managed to harness light effectively.

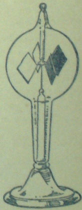


FIG. 22. THE CROOKES' RADIOMETER.

The Radiometer.—This instrument is difficult for the amateur to make because the vanes are contained in a partial vacuum, but they are quite cheap to purchase and an endless source of amusement. The instrument (Fig. 22) consists of four vanes or arms, not unlike those of a weather cock. At the end of each vane is a disc, painted on one side black and on the other silver. Now the black side absorbs heat more quickly than the silver or polished surface, so the instrument is rotated by the sun, which causes the pressure to vary on either side of the vanes. Locomotive steam domes are polished to prevent heat loss by radiation and radiators are blackened so that they will throw off their heat. By placing one of the instruments in front of an electric radiator, you can prove that it is the heat waves and not the light waves from the sun that work the radiometer. The vanes will revolve, just as they would in the sunlight. If you place an iodine cell between the radiator and the radiometer, the vanes continue to work although the iodine cell cuts off all the light waves. But if you place an alum cell between the source of heat and the radiometer, the vanes come to a standstill, although you can see the light passing through the cell. The cell cuts off most of the heat waves which work the instrument.

Heat and Cold.—I have sometimes been asked: "If heat is a source of energy, what is cold?" The answer is, of course, that, actually, there is no such thing as "cold" —the word simply designates a certain degree of heat. Usually we speak of a thing as cold if its temperature is less than that of our bodies, but it is purely a relative term. We talk of the tea being cold when its temperature is about 80 degrees Centigrade, but we should call it "very hot" if we were bathing in this tea! Our hands are exceedingly poor thermometers or measurers of temperature. Take three basins and into the middle one pour a little lukewarm water. In another basin pour very hot, almost boiling water, and into the third water as cold as you can obtain. Now plunge one hand into the very hot and the other into the very cold water. After a couple of minutes, put both hands into the lukewarm basin. The water will feel far hotter to the hand which has been in cold water than to the hand which has been in hot water. If you were asked to answer the question "How hot is this water?" you would not know what to answer, because one hand would be telling you that it was rather hot and the other that it was cold!

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It very soon became obvious to scientists that they would require some much more exact indicator of temperature than the human hand. Glass, metals and air apparently have no feelings and therefore record temperature accurately and not so relatively as human beings. It is a good plan to use a thermometer for testing the temperature of your bath, instead of feeling it with your body. If your hands are very cold, the water will feel almost boiling, but if you have been warming them by the fire it may not feel hot, and you may get into a bath that is unhealthily warm.

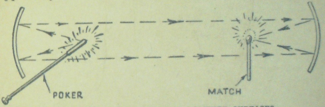

FIG. 23. HEAT REFLECTED BY POLISHED SURFACES.

"Radiant" Heat.—Heat waves behave, in many ways, exactly like those of light; in fact, they are much the same except in wave length. They can be reflected, refracted and split up just as can light waves. Reflected heat is usually called "radiant," and an increasing knowledge of the reflection of heat has resulted in the production of more efficient fires with polished reflectors that throw the heat out into the room instead of allowing it to escape up the chimney.

A simple experiment to show that heat is reflected by polished surfaces can be arranged as follows (Fig. 23). Place two polished concave mirrors, preferably of metal, some distance apart and facing each other. In the focus of one mirror place a red-hot poker and in the focus of the other a piece of tinder or a match. In a few moments the tinder or match will take fire, although you can place your hand between the poker and the match without feeling any appreciable heat. What happens is that the heat rays from the poker are focussed by one mirror, transmitted across the æther, and focussed on to the match by the other mirror. The air only resists their passage if it is still.

You can take advantage of this property of heat to construct, very simply, a "hob" for gas or electric fires (Fig. 24). Obtain a rectangular piece of burnished metal about the length of your fire. Bend it along its length in a curve so that it forms, roughly, a concave mirror. Support it so that when it stands in front of the fire, the heat rays striking the concave surface are reflected straight upwards. If you now place a grill across the top, you will find that kettles will be kept boiling or that toast can be made by placing the bread over the grill. You will probably need to experiment with the exact shape required, but if you imagine the heat waves to be like light it should not be hard. You can, if desired, place a candle in the fire when it is out and then move your reflector about until, on looking straight down at the grill, you see the image of the candle clearly focussed.

Refracted Heat.—Every boy who has used a "burning glass" will know that heat is refracted in almost exactly the same way as light. A simple convex lens taken from a camera and held up to the sun will focus the rays. The little bright spot you see is, of course, light, but since the heat waves travel along the same path, it serves as a useful guide and enables you to set light to matches, paper or anything combustible. I do not doubt that many accidental fires owe their origin to a bowl of gold fish or to some similar ornament, placed on a table by the window, acting as a lens and focussing the sun's heat rays. This is one of the reasons why it is dangerous to leave broken glass lying about on a heath, for a small fragment may act as a refractor and may give rise to a serious fire.

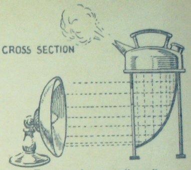

Fig. 24. A simple "hob."

Because it is the æther which is responsible for its transport, heat travels equally well "in vacuo" as in air, and the radiometer is contained in a partial vacuum because there is less resistance to the vanes.

The Burning Glass.—Your knowledge of the burning glass may enable you to win a bet that you can cut a piece of string, sealed inside a bottle, in two. By means of a simple hook, connect a short piece of thin string or cotton to the bottom of the cork and on the end hang a small weight. Now place the cork in the bottle so that the string hangs down, then seal the top. Try to persuade someone to tell you that you cannot cut the weight off without breaking the seal, then go out in the garden, focus the rays of the sun by means of a magnifying glass on to the string and in a few minutes it will be cut in two! If the sun is not available, you may be able to cut the string

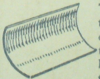

Fig. 24a.

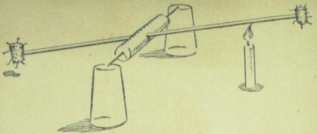

FIG. 25. AN EXPANSION SEE-SAW.

in the same way by focussing the heat rays from a strong gas fire or electric radiator.

Expansion and Contraction.—Generally speaking, when the temperature of a substance is raised, it becomes larger. There is one notable peculiarity in connection with water —which I shall deal with later. Liquids expand more than solids when heated, and gases more than liquids. The tremendous force of expansion and contraction is used in straightening walls that are leaning over. A rod is attached to the wall at one end and to a screw at the other. The centre of the rod is then strongly heated, the screw tightened, and the whole apparatus allowed to cool. When the rod was heated it expanded, and when it cooled, it contracted, the force of contraction being so great that it pulled the wall up into position. It is because of this expansion that the rails on the permanent way of a railway are seldom allowed to touch. The difference in length between the rails of a railroad from London to Edinburgh in winter and summer works out at about 338 yards!

An Expansion See-saw.—A striking method of demonstrating the expansion of solids is by means of a metallic see-saw (Fig. 25). A light rod is required, a curtain rod or piece of stiff wire will do, three corks and some pins. Bore a hole through one of the corks and slip it to the

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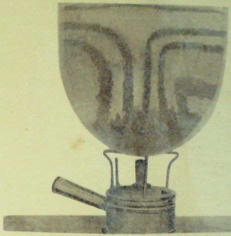


CONVECTION CURRENTS.

If a few grains of aniline dye are dropped into a glass vessel filled with water and this is then heated, convection currents will be seen to carry the colour up in well-defined streams. (See page 70.)

Photo] [*Underwood & Underwood.*

BOILING A KETTLE ON ICE!

Liquid air, with which this kettle is filled, has such a low temperature that ice is intensely hot in comparison and will raise it to its boiling point.

middle of the rod. Then push in two long pins or nails at right angles to the rod, so that the whole balances on the points of the pins or nails. At each end of the rod push on a cork and insert pins until the balance is exact.

Now balance your see-saw—some distance off the top of the table—on the bottoms of two inverted tumblers and gently bring a candle or spirit lamp under one end of the rod. Owing to the influence of the heat, the rod will expand and gradually the arm will fall. If you remove the flame, the rod will contract and the balance will be restored—the process may be speeded up by heating the other side. Thus you can work your see-saw without touching it or blowing upon it in any way.

It is the expansion of the liquid metal mercury that makes the common thermometer possible. Mercury is an excellent liquid for this purpose because it expands evenly at all temperatures, takes up little room and does not suffer from evaporation. Unfortunately, it freezes at a comparatively low temperature—minus 40 degrees C.—so that below this point alcohol thermometers are used, down to a temperature of about minus 132 degrees C. The construction of a mercury thermometer is somewhat difficult at home, but a simple and serviceable airthermometer is easily made.

The Airthermometer.—Fit a thin glass bottle or flask with a cork and through the cork pass some narrow bore glass tubing (Fig. 26). Draw a very small amount of water, coloured with aniline or ink, into the tubing, so that it forms a small blob just above the cork. Place a paper scale behind the glass tubing and then cover the flask or bottle with your hands. The heat of your hands

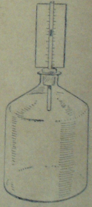


FIG. 26. THE AIRTHERMOMETER.

will warm the air inside the flask, which in expanding will push the "index" up the tube. This, of course, is very rough and ready, so that it will not show great changes in temperature, as the air would expand so much that the index would be expelled.

No two substances expand at exactly the same rate when heated. The term used for the unit rate of expansion is the "coefficient of expansion." The nearest approach is between glass and platinum, and this is extremely useful to the chemist. The platinum wires used in instrument work are sealed into a glass tube which serves as a handle, and even when the platinum is fiercely heated, the glass does not crack. An iron or copper wire, on the other hand, would probably make the glass crack. This similarity of expansion is used in some forms of danger indication in coal mines. One of the few metals which expands as it is cooled is also used commercially for making type, in order that it may closely conform with its surrounding moulds.

Heat may be transferred from place to place in two ways other than by radiation; by conduction or by convection. All substances conduct heat, but some conduct so badly that they are called insulators. On the whole, metals are good, while liquids and gases are comparatively poor conductors. Both air and water are bad conductors. You will realize that air is a bad conductor when you think that, although the heat of the sun may be sufficient to make water steam, it warms the air hardly at all. The upper air is, in fact, very cold, in spite of the fact that heat rays are passing through it continuously to the earth. Heat and light do not leave the sun. It is the ætherial motion which gives us the effects of these changes in various objects on the earth.

It is because air is a bad conductor that furs and knitted clothes are warm. The little layer of air held by the fur or wool forms an insulator which prevents heat escaping.

On the other hand, if your body is cold and you wear a woollen coat, the air will prevent external heat reaching your skin for some time.

Comparing the Conducting Powers of Metals.—An interesting method of comparing the conducting powers of different metals is to procure four strips of the metals, all of the same size. Screw the bars, which may be iron, copper, brass or any other metal, so that they form a cross and on the end of each bar place a small blob of wax (Fig. 27). Now heat the centre of the cross with a candle and watch which blob of wax melts first. You will find that the first to melt is that on the copper bar, the second that on the brass, while iron is last of all. This shows that the heat has been more quickly absorbed and transmitted by the copper than by the iron. You may make this experiment more striking by fixing the live head of a match to the end of the bars in place of the grease. Then there will be no doubt whatever about which is first.

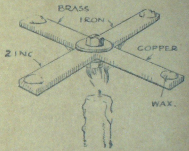


FIG. 27. COMPARING THE CONDUCTION POWER OF METALS.

Copper is an exceedingly good conductor of heat and this property has been made use of in a number of inventions. If you buy some copper gauze from the chemists and hold it over a gas flame, you will find that even when you press the gauze half-way down the flames, the actual flame does not appear above the gauze. The heat is very rapidly conducted away by the copper, and is evenly distributed. This is made use of in the laboratory, where a piece of copper gauze is always placed over the flame when heating a glass flask which might crack if heated directly. The same principle is also employed in the Davy safety lamp, which has saved the lives of countless miners. In this lamp, the flame is completely surrounded by copper gauze so that no flames or heat can come in contact with explosive gases outside.

If you turn on the gas, but do not light it, and then place the gauze on top, you will find that the flame can be lit above the gauze and that it will not spread below. This again is because the copper is conducting nearly all the heat away and preventing it from raising the temperature of the gas below.

"Magic" Candle Extinguisher.—This is easily made out of copper wire (Fig. 28). Wind a piece of copper wire round and round a broom handle or other circular object, so that you have a small coil. Drop this coil over the flame of a candle so that it does not touch the flame, but completely surrounds it. In a few moments the flame will die down and go out. Here again, the copper rapidly absorbs all the heat from the flame, preventing it from vaporizing the wax and eventually putting it out.

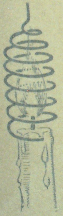


FIG. 28. "MAGIC" CANDLE EXTINGUISHER.

An "Impromptu Kettle."—Water is a very poor conductor of heat, but although this increases the time it takes for a kettle to boil, it can be useful on occasions. For instance, it may be that you have gone out for a picnic and have forgotten the all-important kettle. Provided you have a few sheets of paper, there is no need to worry, for you can soon boil the water for your tea.

Fold one of the sheets of paper into the shape of a case, fill it with water and suspend it by pieces of string or cotton over your fire. The water will boil safely, so long as you prevent the flame from touching that part of the paper which is above the level of the water. The reason why the paper does not catch fire is that the water absorbs the heat, for although it is a bad conductor, it is not so bad as paper.

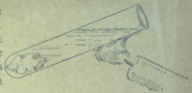


FIG. 29. ICE IN BOILING WATER.

Other Experiments.—In the same way, if you take a thin card, fold up the edges and place in it a piece of tin, you will be able to melt the tin over a flame before the card catches fire. The tin absorbs all the heat before it burns the card. Here is another similar experiment. Take a piece of bright copper or polished steel and stretch over it a piece of muslin. Now drop a glowing coal on the muslin and blow on it to keep it bright. The muslin will not burn for a long time, because the metal absorbs most of the heat.

It is easy to pick a coin out of a hat when the metal of the penny which has been passed round in the warm hands of some friends can be felt by the experimenter to be hotter than a dozen other pennies mixed together. This can be made the basis of a very "clever". trick.

To Make Gas Burn under a Handkerchief.—Take a fine linen handkerchief, and wrap it round a copper gas jet. The jet must be of metal. This is indispensable. Turn on and light the gas, which will burn about the handkerchief without injuring it. To succeed in this experiment it is necessary that the handkerchief shall fit quite closely to the metal without any crease whatever. It will be found advantageous to tie the handkerchief with a thin copper wire.

Ice in Boiling Water.—The most striking proof of the poor conducting powers of water is the boiling of water in which ice remains unmelted (Fig. 29). Place a small lump of ice in the bottom of a test-tube full of water, and by inclining the test-tube, bring a flame under the upper end. In a few minutes the water at the heated end will boil, but the ice at the bottom will remain unmelted. This, of course, would be impossible with a good conductor, for the heat would be carried along and evenly distributed over the ice.

An alternative way of performing this experiment is to place the lump of ice in a tinful of water. You will probably need to weight the ice, as it is lighter than water. Then pour on to the surface of the water some oil or methylated spirits and light it. Even if the oil burns with a fierce flame for a few minutes, the ice will be unmelted.

It is because water is such a poor conductor of heat that the bottom of the sea is very cold. Even in the tropics, where the surface water is warm, the temperature a few feet down is low. You have probably noticed yourself when bathing how it is possible to pass from a "warm patch," to a cold spot quite nearby.

How then, you may ask, does a kettle of water boil, since the heat is not carried through the water from the bottom to the top? The answer is, by "convection." If you had placed the lump of ice on the surface of the water and heated it from underneath you would have found that the ice melted long before the water boiled.

"Convection" Currents.—A few crystals of potassium permanganate will enable you very easily to see the effect of heat on water. Drop three or four crystals into a beaker of cold water and warm the water gently from below (Fig. 30). Almost immediately you will notice a violet-crimson colour rising like smoke from the crystals. The "smoke," which is really water in which the permanganate is dissolved, will rise straight up until it comes to the top of the water, then it will travel along the surface for a little and begin to descend. If it reaches the bottom again before the whole water has taken up the colour, you will see it make another turn and travel up once more.

In this way the heat is distributed by convection. The hot water rises to the surface, descends and is heated again. The reason for this is obvious if you remember that water expands when heated and therefore becomes lighter. Hot water, being lighter than cold, rises to the surface, where it remains until it is comparatively cool, and then it descends again. It is fortunate for us that this is so, or we should not be able to have cheap hot-water systems in our homes. If you examine your hot-water supply, you will find that the hot water always enters the tank or radiator at the bottom, and the cold leaves it at the top, returning to the boiler to be reheated. The exit from the boiler is at the top and the entrance at the bottom.

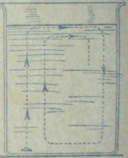


FIG. 30. CONVECTION CURRENTS.

If you cannot obtain potassium permanganate for your experiment, sawdust placed in the bottom of the beaker of water will demonstrate the convection, but not so effectively. We depend on convection for much of our weather. There are currents in the sea because the water is heated in some places and cooled in others; while heated air rises in exactly the same way as heated water, allowing the cool air to sweep in underneath—hence the winds on a summer evening.

It is because hot air rises that we are able to ventilate our rooms. The air heated over the fire, rises up the chimney and the fresh, cold air comes in through the bottom of the windows. In theatres and other large buildings, the outlets for the air are at the top, because all the air heated by the breath of hundreds of people rises to the ceiling.

Expansion of Water.—I have mentioned that water has some peculiar properties of expansion. One of them is that it reaches its maximum density at 39.2° F.—seven degrees above freezing point. If you heat water at this temperature it expands, and if you cool it, expansion again takes place! You cannot make a given amount of water smaller than at this temperature. If it is wintertime, you can perform an interesting experiment to demonstrate this fact; but in summer-time you will need a freezing mixture made of crushed ice and salt.

Take an ordinary hen's egg and "blow it" by means of two small holes, one at each end. After the contents have been removed, seal one hole with wax and in the other place a very small wire hook, fixing it with sealing wax. On the hook hang a small lead weight, such as is used by fishermen. Fill a jar with water at ordinary tap temperature and place the egg in it, adjusting the weight so that it just rests on the bottom. Now place your jar out of doors, if it is frosty, or if the weather is warm, in your freezing mixture. At first the egg will rise slowly, because a fall in temperature causes the water to become more dense. Then there will come a time when the egg remains stationary, after which it will fall and continue falling until ice begins to form. The temperature at which the egg remained still was, of course, 39.2° F. After the temperature had fallen below this point, the water began to expand and the egg therefore sank. If you bring the jar indoors, or remove it from the freezing mixture, you will be able to observe the phenomena taking place all over again.

Boiling and Freezing Points.—These both depend upon atmospheric pressure. For this reason, water boils at a very much lower temperature on a high mountain than at sea level, and connoisseurs say that you cannot make a good cup of tea above 1,000 feet! In some places, such as Mexico, where water boils at 198° F., instead of 212° F. at sea level, it is impossible to cook potatoes properly.

Here is a striking experiment, based on the fact that water boils at a lower temperature under reduced pressure. Fill a glass flask three-quarters full of distilled water and boil it up. Keep it boiling for some minutes until the steam has driven out most of the air, then cork it well while it is still boiling and remove the source of heat.

The water will stop boiling, but if after a minute or two you invert the flask and squeeze a sponge full of cold water over it, the water will begin to boil again and will keep it up for some time. What appears to the uninitiated to be something like magic, boiling water by pouring cold water on it, is quite simply explained. When the air was driven out, the pressure inside the flask was reduced, and the pouring of cold water on the flask reduced the pressure still further by condensing the water vapour. Thus, although the water was at a temperature far below boiling point under ordinary pressure, it was above the boiling point at a pressure of half an atmosphere. If you shake the bottle in which you have the water, you will hear it fall with a curious metallic click, as if it were mercury. There is no air to soften the impact of water against glass. This "hammer effect" can cause damage in steam pipes which are not properly designed.

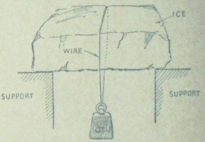


FIG. 31. PASSING A LOOP OF WIRE THROUGH A BLOCK OF ICE WITHOUT CUTTING IT IN TWO.

Impurities and dissolved substances raise the boiling point and lower the freezing point. Water in which there is salt dissolved does not boil until it has reached a temperature of 216 or 218° F., and if you mix salt and ice, you find the whole becomes "slushy," because the freezing point of the mixture is below that of pure water. This is why salt is poured on the pavements when ice has to be brushed away.

Passing a Loop of Wire Through a Block of Ice Without Cutting it in Two.—Increasing the pressure, of course, raises the boiling point and lowers the freezing point. Hence it is possible to pass a loop of wire right through a block of ice without cutting it in two. It can't be done? Well, although it sounds rather like the trick of sawing through the lady which was popular some years ago, this is how to make the test. Obtain a block of ice and support it between two chairs, not forgetting to have a tub to catch the drips! Hang a heavy weight by a large loop of wire and pass the loop over the ice so that the weight hangs straight down (Fig. 31). The wire will cut into the ice, slowly going in further and further. In between half an hour and an hour's time, the wire will have cut right through the ice and the weight will fall to the ground. But the block of ice will remain intact! The wire has passed through it without dividing it into two.

The explanation is simple. The weight exerted on the wire increases the pressure on the ice immediately beneath it. The ice turns to water because of the increased pressure, and the wire cuts through. But as soon as the wire has passed, the pressure returns to normal and the water refreezes. It is this principle which you use when squeezing a snowball. The increased pressure of your hand melts a little of the snow, enabling you to form a ball. As soon as the pressure is released, the snow hardens again. Skaters roll along on a film of water produced by the pressure of their skates upon the ice.

Ice is lighter than water—that is why it floats as it freezes. This means that a pint of water, when frozen, occupies more space than a pint of ice. The force exerted by the expanding water is tremendous—quite as great as metal expanding under the influence of heat. Fill a tin with water to the brim and then put on the lid. Secure the lid firmly with wire, or better still, solder it in position. Now place the tin in a freezing mixture and await results. As soon as ice forms, the tin will open down the seam or push away your solder, because the ice is larger than the water and must escape somehow. Experimenters have broken hollow cannon balls in this way, and no doubt you have had your water pipes broken by a frost. It is this colossal force acting on fissures in rocks and in the ground that produces chasms and even small hills. For the same reason, farmers welcome frost, as it breaks up heavy ground preparatory to cultivation.

All these phenomena in the changes of melting and boiling points are used in modern industry. No modern jam factory, for instance, boils the fruit in open pans. Closed pans are used so that the fruit and sugar can be heated to a high temperature without boiling, which would break up the delicate fruit. The "super-heated" jam is cooked in ten minutes, where before it required two or three hours. "Super-heated" saucepans are also used in many households and, because of the high temperature, the toughest meat can be made tender. At a pressure of twice that of the atmosphere, water does not boil until the temperature is 234° F., and some superheaters go up to three and four atmospheres. Unless the whole pan is enclosed, of course, the water does not rise above 212° F., as all the heat is taken up in converting the water into steam.

How to Reduce Water to Below 0° Centigrade Without Ice Forming.—We speak very freely of the boiling point or freezing point of a liquid, but it is not always realized that this point may be dependant upon conditions apart from those of pressure. For instance, it is possible to cool distilled and air-free water far below its ordinary freezing point of 0° C. without ice forming, provided it is not already in contact with any ice. You can perform this experiment easily, putting in a thermometer and keeping it perfectly still. The water should be cooled down very slowly with a freezing mixture and the greatest care must be taken not to shake it. When freezing does eventually take place, it is exceedingly rapid and extends through the whole liquid almost instantaneously.

A better subject than pure water for this experiment is a solution of "hypo" used by photographers, chemically known as sodium hyposulphite. Make a hot solution of the crystals, adding more and more of the solid, until no more will dissolve. Filter off any surplus while the solution is still hot and then set it in a jar to cool, taking care to avoid any vibration and covering the mouth with paper to prevent the entry of dust particles.

As the solution cools, it continues to hold dissolved much more solid than would normally be the case at the same temperature. Drop in a tiny piece of the solid or even a speck of dust and the whole liquid will crystallize instantly into a solid mass. It is very striking. A solution like this that holds more than the ordinary quantity of solid at a given temperature is called "super-saturated." This can be used as the basis of a trick method of turning "water" into "ice."

"Transition" Points.—Many people talk of "heat" and "temperature" as if they were one and the same thing. They are quite different; indeed, it is possible to abstract or add heat under certain conditions without changing the temperature of the body. This phenomenon is called a "transition." All substances have a transition point—the temperature at which the phenomenon may be observed. Water has two transition points—one at the temperature of steam and the other at freezing point. Steel has several, and very important they are to the engineer or metallurgist.

The transition points of steel can be demonstrated quite simply by stretching an iron wire between two clamps or

convenient holders and marking a small paper scale at the back of one end. If an electric current is passed through the wire from end to end, the wire sags because of its expansion due to heat. If the current is then switched off, it will be noticed that the wire contracts as it cools. Then at a certain temperature it remains still for a second or two and then actually lengthens! This phenomenon is due to the evolution of stored heat as the iron passes one transition point. Different steels have different transition points, depending on their exact composition, and the physical properties of the metals vary at the different transition points.

Geysers which are found in volcanic districts depend for their working on the fact that water under pressure has to be heated far above 212° F., the usual boiling point, before it turns into steam. The water in the geyser is heated from below and the pressure prevents it boiling before a very high temperature is reached. Then suddenly it bursts out, is almost instantly turned into steam when it reaches the normal pressure of the surface, the force shooting the water high into the air. This explains why geysers "spout" with almost clockwork regularity at intervals, instead of continuously.

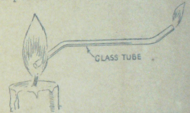


FIG. 32. LIGHTING THE UNBURNT GAS IN A CANDLE.

A Home-made Geyser.—This is not hard to construct. Obtain a long metal tube, and seal it at one end. Taper the other end off to a fine point. The tube should be about three inches wide at the bottom. Fill the tube with water and heat it strongly at the bottom. After a short time, the "geyser" will spout at regular intervals. The steam is prevented from escaping until the pressure becomes very great, when it bursts out with considerable force. This experiment should be performed, for safety's sake, out of doors.

Lighting the Unburnt Gas in a Candle.—Heat is produced by burning or combustion and there is much to be learned even from the burning of a common candle. First, if you look at the flame closely, you will see that it is composed of definite sections or zones. In the centre, near the wick, you will see a zone that is almost colourless. Then towards the outside, you will see a zone that is bright yellow and gives out the actual light. The inner zone consists of unburnt gases. If you bend a piece of glass tubing twice almost at right angles, and place one end in the centre of the flame, the unburnt gas will be led off and can be lit at the other end of the tube (Fig. 32). If the tube is raised a little, so that it is in the bright part of the flame, only a faint smoke will come out of the other end. The actual light is due to the heating of carbon particles.

Why a Petrol Motor Works.—Combustion of any kind is a chemical action. Two elements or compounds unite to form new substances with such vigour that heat, and sometimes light, are produced. It may happen that the resulting products are very much greater in volume than the original materials, and they are made even greater by the heat of the flame. It is this fact which makes the petrol motor possible. An explosion, such as takes place in the cylinder of a motor, is really only very rapid combustion. Modern high-speed cameras have shown that the flame from the spark usually burns relatively slowly down the cylinder. The oxygen and the petrol vapour combine to form gases so hot that they are much greater in volume and the energy of these expanding gases drives the piston.

A Burning Candle Consumes Air.—It is easy to show that a candle consumes air when it burns. Place a small end of candle on a cork or other float, resting it in a basin of water. If you now invert a glass jar over the burning candle, you will see the water slowly rise up, showing that a gas is being used up. The candle will rapidly go out because all the oxygen has been burnt, while carbon di-oxide and nitrogen, neither of which support combustion under ordinary conditions, are left.

Another interesting experiment is to make two tumblers cling together. Light a small candle or a piece of paper in the bottom of one tumbler and place a sheet of paper over the mouth. Then invert the other tumbler over the paper and you will be able to lift up the two together. They cling together because the removal of the oxygen by the burning has created a partial vacuum.

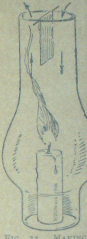


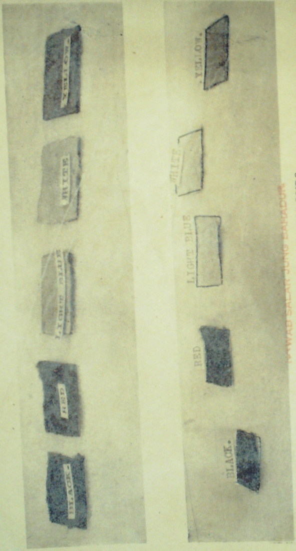
Fig. 33. Making a Candle Burn in a Lampshade.

Making a Candle Burn in a Lampshade.—A candle needs oxygen to burn, and if you can obtain one of those old-fashioned oil lamp shades, with a bulge in the middle, you can perform an interesting experiment in feeding oxygen to a flame. Place the glass shade over a candle and it will quickly go out because the hot air rises and the fresh air cannot get down. Now take a strip of stiff paper, the same width as the diameter of the top of the shade. Fold the paper over a piece of wire, so that it hangs down, and support the wire over the top of the same shade in such a way that the paper divides the chimney into two (Fig. 33). The candle will burn up with a clear light. This is because the hot used air ascends through one side, leaving the other side free for the fresh air to pass down. You can test the currents going up and down with a match flame. You will see it respond to the current.

Why Glass Cracks Easily.—An interesting example of expansion and the power of conduction working against each other is to be found in glass. Every one knows that to pour hot water into a glass is courting disaster and that the thicker the glass, the greater the danger of it breaking. The reason is that although glass expands considerably under the influence of heat, it is a very poor conductor and, therefore, the bottom of the glass expands before the heat can reach the top. The resulting strain means a fracture, although sometimes the fracture is "delayed." The stress is set up, but no actual crack appears until some time later when the glass receives a tap or experiences another change in temperature. There may, therefore, be some scientific basis for the maid's excuse that it "came apart in her hand!" You will seldom break a glass if you hold a silver spoon in it while you pour in the hot water. The silver spoon is a good conductor and carries off the heat, distributing it evenly.

A Novel Way of Cutting Glass.—The habit that glass has of breaking under sudden changes of temperature can, on occasions, be useful. If you have knocked off the neck of a bottle, for instance, there is no need to discard it because of the jagged edges. Dip a piece of string in paraffin or methylated spirits, remove the surplus liquid and tie it round the bottle where you wish it cut. Then set fire to the string. Immediately after it has burned, plunge the glass under water and give it a sharp tap. The top will come off neatly, and can easily be smoothed with emery cloth. You might be able to make a novel set of drinking glasses in this way!

Another method of cutting glass without a diamond is to fill up the bottle with oil to the point where you wish it cut. Heat a poker until it glows red and then plunge it into the oil. You will hear a crack, and the glass will be neatly cut. Glass rings can be produced by merely cutting the glass again an inch or so lower each time.



ABSORPTION OF HEAT BY COLOURS.

Squares of cloth of different colours are placed in the sun on level snow. After an hour or two the colours will have absorbed heat to a greater or less extent and will have sunk into the snow accordingly. (See page 81.)

NAWAB SALAR JUNG BAHADUR

What Colour Absorbs Most Heat ?—Perhaps you know that some colours absorb heat more freely than others. When there is snow on the ground you can prove this in a very interesting way. Cut a number of little squares of cloth or paper of varying colours. You might have black, red, light blue, white and yellow. Arrange the squares on level snow where the sun is shining. Leave them for an hour or two and then come back and see what has happened. You will see that the black square has absorbed so much heat that it has thawed its way down into the snow so that the sun no longer catches it. The red square has also gone down, but not so far. The light blue has absorbed only a little heat and has not sunk very deep into the snow, while the white is still on the surface, showing that there has been hardly any absorption of heat at all. Yellow evidently absorbs heat freely, for this square has sunk well into the snow, but is not so far down as the black.

More Experiments with Heat.—To show how heat can produce distortion, stick a match through the top of its box, leaving the "business" end uppermost. At the other end of the box put half-a-crown and balance another match with the plain end on the coin and the tipped end against the "live" end of the vertical match. Ask someone to remove the half-crown without upsetting the balance and then light the balanced match near the "live" end and wait until the plain part curls safely away. You can complete your match experiment by placing another match between two tumblers and lighting it in the centre. The burning end will stick to the glass and remain suspended in the air. Another experiment, showing the distortion produced by heat, is easily made by cutting a piece of viscose paper into the shape of a fish. When laid upon the hand it wriggles, due to the curling movement.

If you take an empty wine bottle and put a halfpenny on the mouth, with a little water round the rim to seal the join, it can be made to jump out of position by holding the bottle with the hands and thus warming the air until it expands sufficiently to slide the halfpenny out of position.

It is very simple to illustrate the waste which usually takes place when coal is burned in an open grate. Pack the bowl of a clay pipe with powdered soft coal, making a covering cap with moist clay. If the pipe is now put in the fire, leaving the stem projecting, the gas can be lit as it issues and the bowl will be found full of a glutinous tarry residue which contains many kinds of valuable medicines, dyes, and other chemicals. In low temperature coal processes most of the gas and oil is extracted, leaving a fuel which burns somewhat in the fashion of soft coke.

A number of tricks can be performed by making use of the poor conductivity of most objects. If you dip a banana in grain alcohol, it can be ignited and safely eaten if the breath is blown outwards while the banana approaches the mouth.

This makes a better trick than the selection of a penny made warm to the touch by the handling of an audience.

EXPERIMENTS WITH LIGHT

CHAPTER III

EXPERIMENTS WITH LIGHT

What Light is.—Light is a fascinating subject about which scientists are not yet agreed, but we can take it that it is produced by some sort of waves in the æther. It is possible to measure the length of these waves—compared with the length of wireless waves they are exceedingly short, a very small fraction of an inch.

Light does not actually leave the sun. It is the sun which sets the æther into movement and this movement is transmitted to the earth, where it happens to produce the sensation of light. It is only certain wave lengths that we can visually appreciate. Light itself does not exist other than as a human sensation any more than does the smell of an onion. When we come to certain light vibrations such as X-rays, we find that they are invisible, shorter still, and of different type. Light travels as well through a vacuum as it does through air—otherwise we could not have electric lamps. Many electric bulbs are evacuated; hence the " pop " when the glass is accidentally broken.

It is obvious that some lights are brighter than others, and shadows are a convenient means of comparing the brightness of two or more lights. A shadow, of course, is not actually " anything "—it is merely the negation of light just as cold is the absence of an average amount of heat. Darkness is the complete absence of visible light.

The Photometer.—Here is a simple method of settling a dispute about the relative values of two lights. You can use candles for the experiment, or portable electric lamps. Fix a white paper screen at one end of the table and in front of it place some opaque body—an unlighted candle in a stick serves very well because it is thin and long (Fig. 34). Now take the two lamps or candles which you wish to compare and place them in front of the screen, slightly to each side of the unlighted candle. They will throw two shadows on to the screen, each of different intensity. Move the candles backwards and forwards, in a line vertical to the screen, until the shadows they cast seem of the same intensity. Then measure the distances of the lamps from the unlighted candle and their relative values are inversely proportional to the square of the distances. In other words, the further candle gives a better light than that nearer to the screen. This instrument is called a photometer, and is useful for finding the "candle-power" of a light. Originally, candle-power meant the light given by a standard candle, but to-day we have more accurate methods of measurement.

Another good form of this instrument consists of a screen of writing paper with a grease spot in the centre. Place a lighted candle on one side of the screen and the lamp to be measured on the other. You will see the grease spot as a patch of bright light, but if you move the lamp about there will come a time when the grease spot disappears, showing that the same amount of light is falling on it from both sides. The relative values of the lights vary as the square of their distances from the screen. That is to say, if your candle was one foot from the screen and the electric torch or other lamp you were measuring, two feet, the torch is, roughly, giving a light of four candle-power.

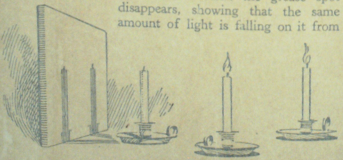


Fig. 34. The photometer.

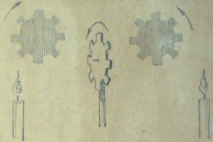


Fig. 35. An interesting phenomenon.

An Interesting Phenomenon.—By a simple device it is possible to make two shadows of a revolving wheel appear to travel in opposite directions. This seemingly impossible feat is accomplished as follows. First make a cardboard wheel about eight inches in diameter and cut teeth in the edge so that the shadow will show which way it is moving (Fig. 35). Fix the wheel by means of a pin in its centre to a stick, so that it spins round easily. If you hold the wheel parallel to the wall in a dark room, with two candles, one each side of it, you will get two shadows, which will revolve in the same direction as the wheel. Now, how can they be made to revolve in opposite directions ? Hold the wheel at right angles to the wall and move it up and down in a line between the candles. All of a sudden you will notice that the shadow is becoming circular. If you now rotate the wheel, you will find that the shadows on the wall move in contrary directions to each other.

The explanation of this phenomenon requires a knowledge of the mathematics of the cone—it is really nothing to do with the light. If you cut sections of a cone parallel to the base, you will find that they are circular, and it is also possible to cut sections inclined to these, which are also circular—they are called the circular sections of Apollonius.

What you did, in effect, when you held up your wheel, was to make the light take sections of an imaginary cone built up on it, and by obtaining the shadows of these sections of Apollonius, you made two shadows of the same object apparently move in different directions. The experiment sounds a little incredible until you have tried it, but it is perfectly genuine and with practice you can find the correct position of the wheel very quickly.

Refraction.—Apart from any astronomical effects, light travels in straight lines unless bent by some external object. This bending is known as refraction, and I shall deal with it a little later. If you wish to see light travelling in a straight line, pull down the blinds in a room which has just been swept, and make a pin-hole in the blind so that the sunlight can stream through. You will see a fine beam of light, and it is absolutely straight, as you can demonstrate by putting a long ruler in it, or by stretching a piece of cotton along its length. As soon as you let the cotton sag, the light disappears.

It is not actually the light which you see, but the reflection of the light from thousands of minute particles of dust. You can also see the light travelling in straight lines if you look at the projector in a cinema. The dust and smoke caused by the audience become brilliantly illuminated in the line of the light, although they are invisible outside it. This beam, travelling to the screen, is perfectly straight, and you can see it apparently moving about as it follows the white parts of the picture. The black, of course, is merely where the light is cut off.

It is shadows that make possible the whole process of photography. The darker parts of a landscape or person do not throw back to the camera so much light as those which are bright. In consequence, in the "negative" these dark parts are shown almost white; the sensitive pigment has not been affected by the light rays. When this negative is placed against a piece of sensitized paper,

the dark parts cut off the sun's light and remain white, while the white translucent portions allow the light to pass through and colour the surface black or brown. In a cinematograph a "positive" is used; the light part lets through the light and therefore appears white on the screen because there is no direct chemical or actinic action.

An Experiment with Four Candles.—Here is an interesting little experiment to show how the rays of light from different sources keep distinct, even if they have to pass through a single opening. Get a rather large piece of cardboard and several candles. Prop the card up vertically below and have the candles arranged in a row on the other side parallel to the broad side of the cardboard and three to four inches from it. Make one pin-hole in the card just at the height of the candle flames. Place a piece of white paper on the far side of the card, light the candles, and darken the room.

How many spots of light will you see falling on the paper? Well, there will be just as many as there are candle flames. All the lights have to find their way through one little hole, yet they sort themselves out when they fall on the paper.

Silhouettes.—These are sometimes very popular and are easily made. Put a light behind your sitter so that the shadow of his profile is cast on a white piece of paper. Move the light about until this shadow is sharply outlined. Then mark round it with a pencil. Afterwards you can black in the picture, or you can reduce it and cut it out. If you now place the remaining "frame" over a piece of sensitive paper and print it in the sunlight, you will have the silhouette in black. Another easy way is to use paper black on one side and white on the other for a screen. You draw the shadow on the white side, cut it out, turn it over, and you will have the silhouette in black ready finished.

Reflection of Light.—Light is reflected by polished surfaces, and one of the laws of light is that, in spite of the nature of the reflecting surface, the ray is always reflected at the same angle as that at which it strikes. In other words, the angle of incidence is equal to the angle of reflection. This may seem a dull academic law, but it has considerable significance in everyday life. Imagine the difficulty of shaving or doing your hair, for instance, if you could never be certain at what angle the light from your head would be reflected! As it is, every man, woman and child makes instinctive use of this law by standing exactly in front of a mirror.

You can prove this for yourself quite simply, using a small piece of thick glass as a reflector. Stand the glass upright on a piece of paper and mark its position with a pencil. Then stick a pin in the paper in front of the mirror and another further away from the mirror, so that the two mark an oblique line to the reflecting surface. Now lower your head and look in the mirror until you see the reflections of the pins. Get them in a straight line and put pins in the spots where they appear to be. Remove the mirror and pins and join up the holes made by the pins. You will find that the angle made to the mirror by the first two pins is the same as that made by the second two pins; also that the apparent position of the images is the same distance from the mirror as the objects. This proves the second law of reflection, that the image is the same distance behind the mirror as is the object in front.

An amusing illusion can be produced by placing a light at a distance of about six feet from a sheet. If you now jump over the candle, it will seem to the audience that the performer, in the form of his own silhouette, is leaping over the heads of those who are watching the sheet.

Reflection by mirrors is the basis of many stage and screen illusions, the best known of which is the "Schauffen" process, employed in some spectacular films of to-day. In this process, used to save the expense of building huge screen sets, such as palaces and elaborate backgrounds, a model is made and reflected into the lens of the camera. Exact measurements make it possible for the actors to play in front of the camera and to appear to be standing on the balcony of a palace or on the stairs of a large house, when, actually, the background is a simple painted cloth.

An interesting illusion, which can be made with a little patience and half a dozen mirrors, makes it possible to "look through a block of stone." The illustration (Fig. 36) shows the arrangement of the apparatus. A "telescope" is apparently divided in two by a large block of stone or wood, but the observer, on placing his eye at the end of the telescope, can see an object placed at the other end of the instrument. The deception is simple. The supports of the telescope are hollow, and the light from the object is reflected down the vertical piece by a mirror. At the bottom another mirror, inclined at an angle, sends the light along a horizontal tube under the block of stone, while two more mirrors reflect it upwards to the eye-piece. If you propose to construct the apparatus for this illusion, which can afford a good deal of amusement, you should coat the inside of the hollow tubes with black paper or paint, so that none of the light is dispersed by reflection from the walls. You will need to experiment with the exact angle at which the mirrors should be inclined, mathematically it should be half a right angle, and if you

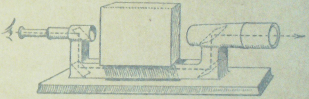


FIG. 36. LOOKING THROUGH A STONE.

mount the mirrors simply on a screw which projects slightly out of the tube, they can be moved about until the object comes into view at the eye-piece.

A Simple Periscope.—This is the principle of the periscope, which is so useful in war and, I am told, in peace, for watching processions and football matches where there is a large crowd. A simple periscope can be constructed out of a long rectangular wooden box, open at both ends. Cut away the wood of one side at each end so as to allow the light to enter and to provide an eye-piece. Then arrange your mirrors at angles so that the image is reflected down the length of the instrument. With this periscope, you will be able to see over walls. Actually, of course, the periscopes used in submarines are far more complicated, using lenses as well as mirrors in order to bring distant objects to a sharp focus.

A useful application of the reflecting mirror principle, if you live in an upper flat, is to screw a large mirror just outside the window so that it reflects upwards an image of the doorstep. Then if the bell rings, you can see, without putting your head out of the window, who it is, and thus save yourself some useless journeys downstairs. In many continental towns nearly every house has a mirror outside the living-room so that the occupants can see who is calling.

The "Talking Head."—If you can secure the use of a number of large mirrors, you can arrange some very striking illusions for parties or bazaars. Perhaps the best is the "Talking Head" (Fig. 37). In this illusion, a head, apparently placed on a table, and with no body visible, answers questions and rolls its eyes and moves its lips. The table has open legs, so that spectators can see nothing is hidden underneath! A subdued light is necessary and the spectators should be kept at a reasonable distance by a rope, or an inquisitive walking-stick may spoil the experiment.

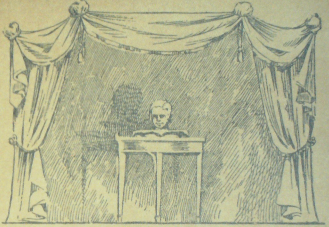


FIG. 37. THE "TALKING HEAD."

The illusion is worked in this way. A hole is cut in the table, through which a man pushes his head. He is comfortably seated underneath on a low chair. Hiding his body from onlookers are three large mirrors, which fit under the table-top. The mirrors are so arranged that they reflect the walls and floor of the bare room, the reflections coinciding with the real walls and ceiling, and thus appearing real. A little experiment is necessary to obtain the exact reflection required, but once the mirrors have been screwed into place, the illusion is remarkable. There is no doubt that it has been used as the basis of many fraudulently produced "spirit" phenomena.

"Ghosts."—Ghosts on the stage are produced in a similar manner and you can give a very fair imitation with the articles available in every home. The real flesh and blood "ghost," covered in a sheet and with rattling chains, walks beneath the stage and is reflected by an inclined mirror on to a transparent screen of muslin placed between the actors and the audience (Fig. 38). The actor can then seem to thrust his sword into the "ghost" without effect!

"Pepper's Ghost."—Smoke can act as a screen and this can be the basis of many illusions, the most popular of which is "Pepper's Ghost." In this illusion the image of a ghost or witch is reflected upwards on to a column of smoke issuing from the apparatus. In the darkness, the image of the ghost is brightly illuminated and appears very realistic.

A better-known form of this illusion is that secured by allowing the public to view some scene through a piece of glass inclined at forty-five degrees to the audience. Another group of persons is situated so that when they are brightly illuminated their image is reflected to those in front of the glass. The original scene can be made to fade away by reducing its lighting as the light upon the reflected scene is increased, and by this simple means one view can be made to fade away as the other appears.

A more modern version of this trick, rather difficult to perform at home, is a ghost that walks amongst the audience, but disappears as soon as the lights go up. For this experiment, barium oxide dust has to be introduced into the room. This dust has the peculiar property of shining brightly in ultra-violet rays and of being invisible in ordinary dull white light. From a hidden lantern the image of the ghost is thrown into the darkened room by ultra-violet light and brilliantly shown up by the barium oxide dust. If one of the audience, becoming suspicious, should suddenly switch on the lights, there will be nothing to be seen, for the ultra-violet light and the dust are both invisible. As soon as the light is turned out, the "ghost" appears again. It can be made to talk through a hidden microphone.

"The Silver Egg."—An amusing illusion, produced by reflection, is "The Silver Egg." Blacken an egg by holding it in a smoky candle flame until it is coated all over with carbon. Then drop it in a bowl of water. Present the

bowl [illegible] ask him if he would not like the beauti[illegible] reposing at the bottom. He will put in [illegible] draw out, not a silver egg, but a black one. T[illegible]planation is simple. The carbon, consisting of very finely divided particles, is not wetted by the water, and holds a very fine film of air, which acts as a mirror and throws back the light to the eye. As soon as the egg

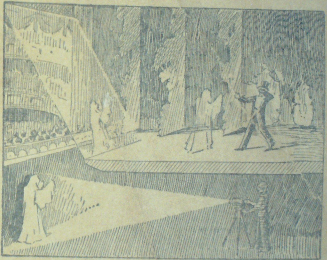


FIG. 38. THE "GHOST."

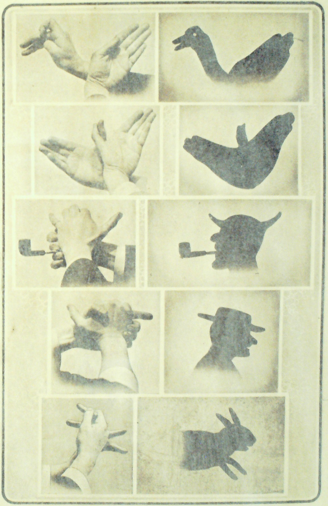
is removed from the water, of course, the film of air is dispersed and the egg appears black. Therefore it is well to remember that all that glitters at the bottom of a pond is not gold; or even silver!

While on the subject of mirrors, it is worth noticing that no one has ever seen himself as others see him. If you stand in front of a mirror, your right hand is the left hand of your image, and your left hand is the right hand of your image. This is, of course, be[illegible] without [illegible]ected in straight lines. No mirror ever [illegible] you yourself as you appear to others, but you [illegible] accustomed to this idea, that you instinctively make the mental adjustment necessary to use the correct hand to, say, remove a smut which the mirror shows you on your left cheek.

Refraction of Light by Water and Other Substances.—One of the oldest experiments with light, it was first performed, I believe, over a thousand years ago by an Arab chemist, demonstrates the refraction or bending of light rays by water. Put a penny, or if you can get it, half-a-crown, in the bottom of a wide-mouthed bowl. Now walk backwards away from the bowl until the coin just disappears from view. Then stop. Now get a friend to pour water into the bowl, and suddenly the penny will appear. Be careful not to move your position during the pouring process.

The explanation is that the rays of light from the coin have been bent, and do not travel straight to your eye. They are bent at the surface of the water, when they pass from the denser to the lighter medium. If you now siphon the water out of the bowl, the coin will again disappear from view. This refraction of the light rays by water explains why it is necessary for the angler to stand well back from the river if he wishes to remain hidden from the fish. Because of their position in the water, the fish can see much further back across the bank than could a man floating on the surface.

Different transparent substances bend light to a varying degree: they have different refractive indices, as the physicist puts it. The substance with the highest known refractive index is diamond, and this is why, when it is cut in small facets, it throws back so many little beams of light. The art of the cutter is to cut the stone in such a way that as many rays of light as possible are refracted



SILHOUETTES. (See page 89.)

and reflected to make it appear "brilliant." It is curious to reflect that the value of this stone depends on a physical property of which the majority of ladies who wear it have never heard!

You can see this difference in refractive indices for yourself by repeating the bowl and coin experiment, this time filling the bowl with turpentine instead of water. You will find that you can step further back without losing sight of the coin than you could with water. This is because its refractive index is about 1.47 compared with 1.33 of water. The refractive index of diamond is 2.60 and of plate glass 1.52.

The bending of light by various substances explains many natural phenomena, the best known of which is the apparent bending of a walking-stick partly immersed in water.

If you have a magic lantern, even a toy model costing half-a-crown will do, there are many interesting experiments that can be performed. You can, for instance, throw a beam on to a mirror supported at an angle so that the light is reflected through a plate glass tank containing water with which a little ink has been mixed. You will see the beam of light bent as it enters the glass, bent again as it leaves the water. You will notice that the beam is not bent so much between the water and the glass as between the water and the air. This is because the water and glass have densities more nearly equal than water and air.

By moving the mirror slowly backwards and forwards, you will find that you can reflect the beam from the surface of the water in the tank. It will be thrown back to the bottom and once more reflected, this time out of the tank. The reflecting power of the surface of water can be seen in any pond or river, and partly explains why the sea seems bluer on a fine day, when the sky is clear, than on a grey day, when the sky is clouded. A glass of plain water, looked at from underneath, gives a good example of total reflection.

Different parts of the same substance at different temperatures may act as refracting surfaces. Thus, when a ray of light passes from warm air to colder air, it is bent. You may have noticed what appears to be hot air rising over a coke fire. Actually, it is not hot air or smoke, but simply the "light" being bent at a number of angles as it enters the region of hot air. This gives a wavy appearance, not unlike smoke ascending.

When the refracting surface is curved, the ray of light is bent even more. If it is curved in one way, the ray is bent further back; if in the other, in the opposite direction. In other words, a convex lens, which bulges outwards, brings a parallel beam of light to a focus; and a concave lens, bending inwards, spreads it out. A simple magnifying glass is a convex lens, and so is the lens in your eye.

The Human Eye.—This has many limitations, as I shall show you, but on the whole it is an amazingly automatic, but mechanically faulty, optical instrument. It adapts itself instantly to all kinds of conditions, brings objects at all distances to a focus and appears to be capable of almost unlimited service. It can get to work in a small fraction of a second, for it has been calculated by means of experiments with an electric spark that the eye can see the printed letters on a page in forty billionths of a second! But, curiously enough, when we try to look at a very faint star it seems to disappear. The best way to see it again is to concentrate the vision on a spot a little distance away from it, when it will immediately return to sight!

The "Blind Spot."—As most people know, when light enters the eye, it is focussed by the lens on the sensitive retina, from which nerves carry the impressions to the brain. There is one spot in the retina where the optic nerve enters the eye and this is responsible for the phenomenon of the "blind spot." A simple way to show the existence of this spot is to draw a small cross on a piece of white paper and, about two or three inches away, a small black dot (Fig. 39). If you hold the paper at arm's length, you will be able to see both the spot and the cross, but if you close one eye and keep the other fixed on the cross, bringing the paper closer and closer to your eye, you will find that the spot suddenly disappears from view. If you now bring the paper still closer to your eye, you will find that the spot reappears.

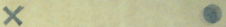


FIG. 39. THE "BLIND SPOT."

The spot usually vanishes about eight or nine inches from the eye. It is difficult, therefore, to believe the excuse of cricketers who explain their scattered stumps by saying that the ball was on their blind spot!

If you examine most good cameras, you will find an iris that may be opened and closed according to the amount of light available, the length of the exposure, and other conditions. The eye has an iris of a similar type, except that it is automatic and beautifully graded. You can see its action easily in cats. In bright sunlight, the pupil of a cat's eye seems a mere pin-head, but in a half-light, or even in artificial light, the iris opens and the pupil appears much larger. Get a friend to look at a strong light for a second or two and then look away. If you look into his eye, you will see the iris close as he looks at the strong light, and then open again slowly when he looks away. You can even observe this in your own eye by looking in a mirror and moving a source of light first nearer and then further away from your face.

The lens in the eye, of course, inverts all images. The reason why we do not see things upside down is simply that the nerves and brain have the power of returning the

Fig. 40.

impressions to normal. I have not often heard of a person suffering from a disease in which the images refused to be re-inverted, but it is quite understandable that such an infliction can exist. If you wish to see the action of a lens without going to the expense of obtaining one, a pin-hole in a piece of paper will serve excellently.

Stand the paper upright in a darkened room, then place a candle in front of it. Next, using another piece of paper as a screen, move the candle about until you focus the image through the pin-hole on a screen. You will see the flame burning, apparently, upside down. If you were able to throw an image on the retina without allowing it to be inverted, you would also see it upside down. Here is a method by which you can bring this to pass. You need only a small piece of cardboard and a pin for the experiment. Make a pin-hole in the cardboard and, holding it in front of your eye, look through it at the electric light. Then hold a pin closer to your eye. You will see it apparently inverted! The explanation is simple. The pin-hole in the cardboard acts as a preliminary lens, inverting the image of the pin so that the pin appears upright on your retina. Your nerves, acting according to experience, turn the image upside down, a process which usually brings it the right way up, but in this case results in your seeing the pin upside down.

The fact that the eye is easily deceived is the basis of scores of optical illusions (see Chapter VII). Some of them are used in everyday life. For instance, a lady inclined to be stout knows that she looks better in black than in white clothes. But she does not understand why. The reason is that white, because it reflects most light, impresses itself on the eye longer than black, and, therefore, makes objects look larger than they really are. In the

same way, we all know that a stout man will look thinner in a suit with vertical stripes, and fatter in a suit with horizontal stripes.

Each of our eyes sees separately, although they only work at their best in conjunction. With one eye you cannot judge distances accurately—with two eyes you can do so because habit enables the brain to tell where the two lines of vision cross. For this reason it is sometimes considered unsafe for people with one eye to motor, and I cannot imagine a person with one eye making a really good billiards player. It is because we have two eyes that we are able to see objects in three dimensions, or, as it is often called, stereoscopically. We feel that, when we look at something, we can see behind it. Because a photograph is, so to speak, taken with only one eye, it appears flat and comparatively lifeless. Stereoscopic cameras have two lenses and two plates arranged to represent the viewpoints of two eyes. When a picture is taken simultaneously with these two cameras, and the resulting pictures placed in a "stereoscope," which combines the vision of the two eyes, the landscape stands out in a remarkable fashion.

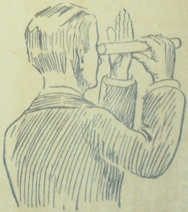


Fig. 41. Looking through your hand.

"Looking Through Your Hand." — An amusing illusion that can be produced as a result of this knowledge is "looking through your hand." If you offer to show a friend a view through his hand, he will probably reply that it cannot be done as flesh is opaque except to X-rays. Offer him a tube of paper, six or eight inches in length (Fig. 40), and make him place it to his right eye. Then get him to hold his left hand half-way down the tube in front of his left eye and ask him what he sees (Fig. 41). He will see, apparently, a hole in his hand, through which he can see the objects in the room. The explanation you will give to him will be, of course, that the right eye was seeing things through the tube over a limited compass, while the left eye was having its view blocked; the result being that the eyes deceived the brain into thinking that he was looking through the solid hand. It is only an accident of birth which makes our eyes sensitive to light of specific wavelengths. Heat rays can be used photographically to a limited degree.

All these illusions teach us the danger of jumping to conclusions regarding the things we see. We all know stories of travellers in the desert who have walked for hours towards an oasis, only to find that it was a mirage and did not, in fact, exist at all. There is much the same danger in everyday life if you rely entirely upon your senses without knowing their weaknesses.

Persistence of Vision.—Another shortcoming of the eye is called "persistence of vision." If you are shown a rapid succession of pictures of the same man in the same position, you think you are looking at the same picture all the time. The eye "carries over" the vision of one picture to the next so that they appear to be the same. One of the most popular entertainments of to-day relies on this optical illusion for its effect. I refer to the cinematograph. When you look at the screen, you think you see figures or pictures of figures moving. You actually see nothing of the sort. You see a series of detached pictures, but the eye is too slow to divide them and you cannot distinguish each separate picture. No one would realize that sixteen times a second the light is entirely cut off from the screen! This illusion can easily be seen in many ways. A piece of string, which is smouldering at one end, when whirled round appears to be a continuous ring of fire. When you whirl some of the diagrams on these pages round, you will see them apparently moving. In the same way, the spokes of a wheel of a moving motor-car seem to be continuous although a camera opened for one-thousandth of a second, a much shorter period of time than the eye can appreciate, shows them to be perfectly still.

The phenomenon of persistence of vision can be demonstrated by rotating a disc which is black on one side and white on the other. Cut your disc out of cardboard, making it two inches in diameter. Make two small holes, one each side of the diameter on either side of the disc, and thread through each a piece of string about nine inches long. Knot the strings so that you have two loops. By twisting the loops and pulling with your hands, you will be able to make the disc rotate very rapidly. You will see that it appears to be grey—the shade half-way between black and white. If you use other "colours," the resulting colour will always be a blend of the two—the same tint as you would get if you mixed the corresponding water colours.

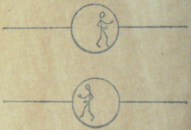


FIG. 42. WHEN THE DISC IS ROTATED, THE FIGURES APPEAR TO BOX.

Make a similar disc and paint in the centre a coloured star. The remainder of the disc should be some neutral colour. When you rotate the disc, you will see that the centre takes the colour of the star, while the edges take the neutral colour of the background. This failing of the eye can be made the basis of countless illusions. Prepare a disc similar to those you have used, and paint on one side the picture of a bird and on the other the picture of a cage. Now rotate your disc and you will see the bird inside the cage! The vision of the bird persists sufficiently long to impose it over that of the cage, and the bird seems to have stepped inside the bars. In this way you can combine all sorts of pictures—you can have a cricketer with a bat on one side and a set of stumps on the other, or you may have him with his bat on the ground in one picture and with it lifted up in the air on the next, when he will appear to be hitting a ball very jerkily and very quickly, if the card is not moving too fast. In the same way, you can draw two boxers, one either side of the disc, one being to the left of the circle, the other to the right, as shown in Fig. 42. When the disc is rotated, the figures will appear to box.

The Zootrope.—There used to be a very popular toy called the Zootrope, which was really the forerunner of the cinematograph. This toy can easily be constructed. It consists of a circular band of thin cardboard in which long rectangular slits are cut at regular intervals (Fig. 44). The cardboard band turns on a horizontal axis and inside is placed a paper strip on which are drawn successive pictures of a movement (Fig. 43). Thus you can have, say, a girl skipping with a rope or two boxers fighting in a ring. If you rotate the instrument rapidly and peer through the slits, you will see movements which appear to be continuous. The light is cut off at regular intervals, just as it is with a cinematograph film, so it is surprising that this toy, which was popular fifty years ago, did not lead sooner to the invention of the moving picture as we know it to-day. The real difficulty lay in making the photographic film.

The Phenatascope.—Another scientific toy which was popular some years ago was the phenatascope. It was not

FIG. 43. THE ZOOTROPE STRIP.

nearly as bad as it sounds. It is an instrument somewhat resembling a Praxinoscope, and in principle is exactly the same as the Zootrope, but is simpler to construct. You require two large discs of cardboard, one black and the other white (Fig. 45). On the white disc you paste pictures of a boy performing consecutive actions, just like those on the band of the Zootrope, except that the pictures are arranged clockwise. Then you cut long slits in the black disc to correspond with the centre of each of the pictures. It is important that the slits should exactly fit. Finally, fix the two discs at opposite ends of a metal rod, held so that it can be revolved horizontally. If you give the discs a spin, and peer through the rectangular slits, you will see the figure in movement.

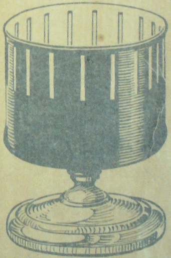


FIG. 44. THE ZOOTROPE.

The Kaleidoscope.—This is a simple piece of apparatus for producing patterns from a drawing by reflection. The simplest form consists of two mirrors, hinged by a piece of sticking paper. The mirrors are stood at right angles, and the object to be "kaleidoscoped," so to speak, is placed between them. The numerous reflections make a pretty pattern when looked at from the front. Any can be made the [illegible] to place in the instrument, or you disc similar [illegible] objects, such as a lump of sealing wax the [illegible] of broken coloured glass.

What is Colour ?—An illusion which nearly all of us cherish is that things have "colour." Actually, of course, the only thing that has colour is light itself. The sea looks blue because it absorbs all the light rays except those which are blue. A piece of paper is white because it reflects all the colours of the visible spectrum, which combined give the effect of whiteness, and ink looks black because it absorbs every colour, and reflects none. You will remember that I have explained black to be only the negation or absence of light.

There may be many colours which we cannot see because our eyes are not sufficiently sensitive. Some experts hold that there are 165 different "primary" colours, and we can see but four. Even these we only observe with a small part of the eye. The retina, or sensitive screen of the eye, is sensitive to colours only in a comparatively small spot near the centre. Here is a method which enables you to prove this for yourself.

If you divide your vision, by holding the edge of a black card to your nose, and then hold a blue card in front of your left eye and a yellow card in front of your right eye, you will see not blue and yellow, but dirty white. Possibly you will experience a competition between the two colours—the result varies with different people. If you repeat the experiment with red and green cards, you will find the result is very much the same.

Colour vision is supposed to take place only at some very small point, made up of "cones" which slope on both sides to "rods." The cones are supposed to be sensitive to colours, while the rods are not, giving only grey, black and white vision. Cats are believed to be "monochromatic," that is, sensitive to only one colour, white, so that they see a very grey world about them!

Another good demonstration of this lack of colour vision is to fix your eyes on a spot directly in front of you and then to ask a friend to move cards of different colours from behind your head to one side and to the front. Under correct lighting conditions, you see that at first all cards appear grey instead of in their true colours. But as soon as the cards come directly in front of you, that is, before the colour sensitive spots, they appear quite normally coloured.

Colour-blindness.—Quite a number of men, nearly one in ten, are more or less "colour-blind." That is to say, they do not see colours as do the majority of us, but they confuse certain colours and often see red as black. There are many different types of colour-blindness, but if you wish to know how the commonest type of colour-blind man sees things, procure some green-blue glass from a dealer. I believe the colour is called technically "signal glass." Out of a sheet of this glass, make yourself a pair of spectacles or a reading glass—they need be only quite rough.

The glasses will cut off all red light, and you will find that you make ridiculous mistakes in matching colours. You will, for instance, find it exceedingly difficult to distinguish between red and black-brown colours. One good test is to select a red strand of wool and

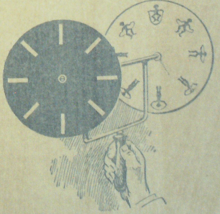


FIG. 45. THE PHENATASCOPE.

then to mix it up with a dozen strands of wool ranging in colour from jet black to light grey. Then try to pick out the red strand while wearing your special glasses. The chances are against your succeeding, you will probably pick out a drab-coloured piece of wool. Another similar test is to try to pick out a piece of pink wool from strands of blue. Here again you will probably be unable to distinguish the colours.

With lantern slides made of this coloured glass, you can provide endless amusement for an audience and, incidentally, enable them to appreciate the difficulties of the man who is colour-blind. A double thickness of glass may be necessary in making the slides, which, when in the lantern, will prevent any rays of red light from reaching beyond them. You and your audience, therefore, will be colour-blind—that is, although your eyes are sensitive to red light, there will be no red light to see. The light issuing from the lantern will look quite ordinary as reflected by the minute dust particles in the air, in fact, until an ordinary white light is switched on, you will not suspect that there is anything abnormal at all.

Now if you have a picture of, say, John Peel in his red hunting coat, an advertisement poster would serve very well, you can ask one of your audience to step forward and state what coloured coat he thinks the man is wearing. If he is honest, and does not guess, he will probably say "black" or "drab," for this is how the coat will appear in the "doped" light from the lantern. Everyone in the room will agree. Then if you turn up the lights, or put an ordinary plain glass slide in your lantern, the coat will appear bright scarlet, and you will have considerable difficulty in convincing your astonished audience that you have not changed the pictures by sleight of hand.

An alternative is to wear a brilliant red tie with a black coat and trousers, and to ask your audience whether they think your tie matches your suit. They will probably reply that they see nothing wrong with it—but they will change their opinions when you turn on the ordinary light! This method is used, of course, a good deal on the stage, where the "spot lights" can make a dress appear of half a dozen different shades in as many minutes. Even ultra-violet light is now used for theatrical effects and special fluorescent materials are added to every costume. In one form of imitation stereoscopy the audience are given glasses with one red and one green lens. Alternate pictures in red and green, taken from cameras a slight distance apart, are displayed so that the two views are finally combined by the brain into one perspective.

How to Match Patterned Cloths.—I believe that women sometimes find difficulty in matching a plain cloth against a patterned one of a different shade. A simple way to ensure that there is no "clash" is to find the "general" colour of the patterned material, then there is little difficulty in matching. Make a small cardboard top, by cutting a disc out of stiff cardboard and putting a sharpened pencil through the centre. This should spin quite effectively when given a twist with the fingers. If you now cover your top with the patterned material and set the top spinning, the various colours will blend and give you a tone. It should be a simple matter to match another colour, but if you are still in difficulties, make a small edging on the top of the proposed second material. Now, when the top spins, you will see two distinct colours, one caused by the patterned material, and the second by the matching material. You will easily see whether the colours tone or blend.

Complementary Colours.—The experiments which you made with "after images" with black and white subjects can be repeated with coloured objects. In the case of colours, the after image will be of the complementary colour; green will give a red after image, and orange will give blue. Prepare a piece of cardboard which is equally divided into three by having bands of three differently coloured papers pasted across it. Support the cardboard upright on the table, and, sitting in front of it, gaze at the colours steadily. After a minute, slip a piece of white paper over the cardboard, and you will see appear before your eyes three bands of the "complementary" colours.

The scientific explanation of this phenomenon is that the eye becomes tired when looking at a given colour. When, immediately afterwards, white is presented to it, the eye refuses to respond to the rays producing that colour, and as a result the complementary colour, which mixed with the original gives a "neutral" colour, appears.

By means of the photometer which you have constructed for comparing the intensity of two lights (page 86), you can produce coloured shadows—a remarkable phenomenon, which is very puzzling when first seen. Having arranged your unlighted candle or pencil which is to provide the shadow, move your two lights about until the shadows overlap in a very dark part. The remaining parts of the shadow must be of equal intensity. You will understand that for this test, with two lights of equal strength, they must be equidistant from the candle. Now in front of one of your lights place a piece of red glass. The immediate effect will be to turn the shadow red and green. You can understand part of the shadow becoming red, of course, but where, you may well ask, does the green come from? That question even experts are not able to answer completely satisfactorily, but it is generally supposed that it is due to some physiological effect of the "after image."

If you repeat the experiment, using a blue glass in place of the red one, the shadow will appear blue and yellow. You can use any colour you choose, and in every case, one half of the shadow will be illuminated with the coloured light, while the other will give the complementary colour. This is one of the difficulties of colour photography. Only too often the beautiful purple and red tints do not

appear on the plate, and no device can make them appear, for they exist only in our eyes! Modern science suggests that the man who said "Seeing is Believing" was a long way from the truth!

"The Interference of Light."—A very interesting mirror can be made with a piece of mica—although if you cannot obtain a sheet of this substance from a hardware dealer, very thin flexible glass or gelatine will serve almost as well. In a darkened room prepare a spirit lamp by sprinkling on it a little common salt, so that it gives only yellow light. The sodium in the salt gives the flame a characteristic yellow, and the light is "monochromatic," that is to say, it gives out only the yellow band of rays of the spectrum. This is one way of conducting a delicate analysis, by using a spectroscope to split up the light given by a material when it is glowing, and examining its component parts.

Now, holding your piece of mica between finger and thumb, bend it back slightly and position it in front of the spirit lamp. You will at once see the reflection of the flame and across it a number of dark bands. If you now look at the mica in ordinary light, you will see the dark bands are no longer there. How are they produced?

The phenomenon was first observed by the British chemist Young about a century ago and is called "The Interference of Light." The explanation depends on the theory that light is a form of wave motion, and that when the crests and troughs of one ray coincide with the crests and troughs of another, the motion is annihilated and blackness results. You can call it "hetrodyning" if you like; a comparable phenomenon occurs in sound, giving zones of silence. So when one ray strikes the front of your mica mirror and coincides with another ray hitting the back of it, you obtain a black band. It is necessary to have monochromatic light because white light is made up of waves of many different lengths. You can repeat the substance using other lights of different colours. A little copper salt will give you a green light; a little strontium, a red light.

"Newton's Rings."—Isaac Newton observed this phenomenon and suggested another easy way of observing the bands which are known as "Newton's Rings." Make a strong soap bubble in the manner described under the physics section (page 177), and let it alight in a glass tumbler so that it is supported by the brim. Then place a candle behind the bubble and on the other side a focussing screen of frosted glass, a piece of translucent paper stretched tightly in a frame, or a cardboard sheet. After a few minutes, a band of colours will appear on the screen, and as the soap bubble drains, they will increase in intensity. A useful precaution to ensure long life to your soap bubble is to coat the glass holding it with glycerine. The colours will change constantly because of the varying density of the film. If you perform this experiment with one of the monochromatic lights I have described, you will see dark bands like those seen in the mica mirror.

Diffusion of Light.—A common phenomenon connected with light, which we all see every day of the week, is "diffusion." If you look at a street lamp on a wet day, you see the light apparently spreading out in streaks—this, indeed, is how an artist would represent it. Actually, the light is radiating equally, and we are deceived into seeing it as moving streaks by the phenomenon of diffusion. This is not quite the same as the radiant points from a star which may be due to the "ridges" which occur on most human eyes.

Don Quixote's Windmill.—The same effect is obtained if you look at a light through a sheet of fine gauze, and here the light appears as a luminous cross, which seems to move. This can be turned to good effect for an illusion known as "Don Quixote's Windmill." Make a small model of a windmill without sails. In the upper window

THE VISIBLE SPECTRUM.

A glass prism splits up light, and the "spectrum" can be magnified by a lens and cast on a screen. (See page 113.)

cut a hole and place some sort of light inside—a candle will serve. Now switch out the light. Your friends will probably say that the windmill is unfinished as it has no sails. You can tell them, if you like, that they are blind, and hand them a small frame of silk gauze tightly stretched. On looking through this gauze at the windmill, they will see that it has apparently luminous sails. This is due, of course, to the diffusion of the light coming from the upper window which is spread out like a cross. If the silk is rotated round and round, the sails will appear to revolve. The explanation of this phenomenon is that light is split up as it passes through small solid particles. In the case of a wet lamp, it is the small raindrops; in the case of the silk frame, it is the silk. The smaller the particles, the greater the diffusion.

The Sunset.—This effect is responsible for many of the beauties of the sunset. The fine dust particles in the air split up some rays and absorb others. We see the splitting up at sunset and sunrise because the light rays have to travel through a greater body of dust particles than they do when the sun is overhead, although if you live in a large city, you have probably seen the sun as a red ball in the middle of the day during a fog. The dirt particles absorb all the light rays except the red, which are at the lower end of the spectrum and have the greatest penetrating power. It is for this reason that red lights are used on aerodromes—they are visible to aeroplanes when white and blue lights would be quite hidden by fog.

The Visible Spectrum.—With a glass prism you
split up light and see the "spectrum" on a screen.
experiment must be performed in a darkened ro
you have lenses to produce a small ray of light fro
or lantern, so much the better; otherwise, ch
into which the sun is streaming and make
the blind. Allow the ray to impinge on a
and put a paper screen behind it. You w

CHAPTER IV

EXPERIMENTS WITH SOUND

SOUND, like light and heat, is caused by oscillations, but unlike light and heat, it requires some definite substance in which to vibrate. Light and heat can travel through a vacuum, but not so sound. If you have an air pump, you can prove this for yourself. Put an electric bell under a large glass jar, placed upside down on a well-greased wooden plate through which two holes have been bored to admit the electric wires. Make a third hole for your air pump and render all the joins quite airtight with strong wax. Now set your bell ringing by switching on the current. Work the air pump and the ringing of the bell, which is very loud at first, will become fainter and fainter, eventually dying away altogether. If you now allow the air to enter once more, you will hear the bell faintly at first, and more and more distinctly as the air fills the vacuum.

Sound is Caused by Vibrations.—That sound is caused by vibrations can be shown in a number of ways. Place a knitting needle or other springy piece of steel in a vice and clamp it tightly. Give the end of the needle a sharp tap and you will hear a high singing sound emitted. If the needle is very flexible, you will see its end traversing an oval shape very rapidly; indeed, so rapidly that the persistence of vision will make it look like a tapering vase or champagne glass.

The Tuning Fork.—If you examine a tuning fork when it is sounding, you will notice that the prongs are moving very rapidly over a small distance. An ordinary table fork can be made to emit a note if it is struck sharply on one of the prongs and then the handle is held firmly against the wood of the table. The table-top will act as a sounding board and will amplify the musical note given out by the fork. The vibrations from the fork are transmitted to the wood, which vibrates in sympathy, and the sound waves thus set up cause the drum of your ear to oscillate in response while your brain interprets the sounds. When you think of the range of the scales, of the endless variations of chords and tones produced by different instruments, you will marvel at the number of possible wavelengths and combinations of wavelengths which the human ear can select, classify and appreciate.

The Human Ear.—Yet the ear, like the human eye, is not a perfect scientific instrument. It is, for instance, sometimes more sensitive after a heavy meal than when the stomach is empty, and the vibrations it can hear must be between sixteen a second and some thousands a second. The irritant value of a note is not always decided by its audibility. Some people can hear much higher notes than others, and investigations show that we can hear the more rapid upper pitch vibrations better in youth than in old age.

A "Silent" Dog Whistle.—Animals, of course, can hear higher notes than we can, and with a little ingenuity it is possible to make a whistle that cannot be heard by human beings, but to which a dog answers readily. It is for this reason that dogs are often so sensitive to music, they catch some of the very high "overtones" which escape our ears, and you will find that the instrument to which they are most sensitive is the violin, which is especially rich in overtones. "Silent" dog whistles are best made by cutting a small piece at a time from the length of an ordinary whistle which has been plugged at the end. It should be cut until, to human ears, it loses all musical note and sounds like the hiss of escaping steam.

A man cannot hear this sound at one hundred yards, but most dogs will respond immediately.

How to Hear Like an Antelope.—If you are an amateur wireless constructor and can secure a microphone cheaply, you can make a very amusing instrument which will enable you to hear like an antelope. We know that these animals in the wild state, especially, have very sharp ears, and the instrument will make you realize how kind Nature has been in making our hearing less sensitive to sound!

First, make out of wood or metal a horn for catching the sound. This may have endless varieties of shape, but the easiest is like a megaphone. If metal is used, bind it with glued tape to remove some of its resonance. At the end of this place your microphone, and carry the wires to an amplifier, two valves should be sufficient. Now place the instrument facing down the road and "listen in" on a pair of earphones. With such an apparatus I have heard the thud, thud of a policeman's footsteps at dead of night when he was a hundred yards away and overheard parts of a conversation taking place in the house opposite! Life in a civilized town would be intolerable if we heard like this all the time!

It is interesting to remember that, with an increase of intelligence and nervous sensitivity, man is losing some of his acute senses and that he may need many forms of mechanical aid in the distant future. At present, although we have the largest average range of senses, individually these are less developed than in some of the humblest of creatures.

No man can feel so delicately as a spider, hear worms under the ground like a bird, or sense the tread of a thrush's foot, as can a worm beneath the earth's surface. Even bats seem to possess some sensation of sight in darkness which has long been atrophied in man.

To return to our fork vibrating on the table. If you use an empty cigar box as a sounding box, and cover it with very fine powder, you will see the powder dance up and down in response to the vibrations.

"String Instruments."—This is what happens in the "string instruments," such as the violin, the 'cello and the double bass. In the case of the huge double bass, you can see the strings vibrating easily enough and feel the wood trembling in sympathy. The texture of the wood, the way it is treated, its shape and a hundred other points decide the "quality" of the note emitted, and thus it is that Stradivarius violins are worth a fortune, because of the perfection of their design and workmanship. There is another point—musicians value their violins because of the "purity" of the notes they give. This means that there are no extraneous vibrations—only the musical overtones. It is possible, therefore, that in the case of the old violins, the beauty of the sound they emit depends upon the amount which they have been played. All the particles of the wood have been "put into their places," and so give no trouble with unwanted sounds. In the future we may have machines constructed to play violins night and day for a year or two to produce perfect instruments!

The Singing Wine Glass.—Everyone is familiar with the singing wine glass which gives out a musical note when the wetted rim is stroked with the finger. If there is water in the glass, you will see when you rub the edge that little waves are produced on the water. If, instead of running your finger round the glass, you rub it in one place only, you will find that the waves, instead of occurring all over the surface of the water, occupy only definite positions, other parts remaining perfectly calm.

The explanation is that the wine glass vibrates in sections forming "nodes," or places where there is no vibration. You will find that these nodes occur at the point where you are rubbing, at a point exactly opposite on the other side of the glass and at two other spots which, when

connected by an imaginary line, form a diameter crossing the first at right angles. Between these four nodes, you will find four other places where there is very violent agitation.

To make the nodes more easily seen, cut a cross out of paper, place it symmetrically over the glass and bend the edges of the arms down over the rim. You can then make the cross follow your finger round the glass by rubbing slightly to one side of one arm. If you rub directly under one arm, you will find that the cross remains undisturbed, but if you rub to one side, the cross is no longer resting over the nodes, and the agitation will tend to send it towards the places where there is no vibration, that is, over your finger. Move your finger on a little further and the cross will follow.

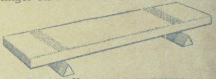


Fig. 45. Vibrating bar of steel.

Dislodging the Rider.—A popular after-dinner trick when wine glasses were under discussion used to be to tear a tiny piece of paper, double it over, and place it so that it "sat astride" the wine glass. The problem was to dislodge the "rider" without touching it. Anyone who understood nodes, of course, simply drew an imaginary diameter across the glass from the "rider," and then rubbed his finger on the glass an eighth of a circle away. The rider was then immediately thrown off. If you rub your finger exactly opposite the rider, you will observe it jump a little, but it will not come off. When you perform these experiments with wine glasses, by the way, the thinner the glass the better, and make sure that the points where the paper rests are perfectly dry, or the paper will stick. Quite a good tune can be played by tapping on bottles which have been filled to suitable heights with water until the requisite tone is obtained.

Vibrating Bar of Steel.—You will be able to show the existence of nodes very well with a steel bar, which can be made to vibrate by striking it with a light hammer when it is resting on two ridge-shaped supports (Fig. 46). If you support the bar near the ends and cover it with a light dry powder, you will find on striking that all the powder jumps into little heaps, making straight lines over the supports. These are the nodes, for the powder naturally makes for the spots where there is no vibration. If you now move the supports nearer the centre of the bar and strike it again you will find that there are four nodes, dividing the bar into four equal parts. It is unnecessary to enter into the technical explanation of nodes, or the anti-nodes as the points of greatest vibration are called, but the subject is of great importance to acoustical engineers, who have to make a voice on the stage reach every part of a large concert hall and frequently employ special absorbents and reflectors to prevent the ingress of unwanted noise.

Wavelengths.—If you are dealing with two sounds of different wavelengths, you will see that at intervals the crest of one wave will coincide with the trough of another, just as in the case of the light waves that produce the dark bands on the mica mirror. There are several ways in which you can see this happening with sound. The simplest is to take a strong piece of clock spring, straighten it, and then twist it with a vice so that the broadest part of one half is at right angles to the broadest part of the other. Next clamp one end very firmly in the vice and attach a minute globule of mercury to the upper end with a little grease.

Lissajous' Figures.—Set the spring vibrating and you will find that the mercury is traversing a double figure of eight. The eight may be bent to the right or to the left, or the figure may be rather more complicated than a simple eight. You can produce the simple form by experimenting with the length of spring held in the jaws. These figures are known as Lissajous' figures and later on you will see that they bear a remarkable resemblance to the "harmonic" figures produced by two pendulums swinging in opposite planes.

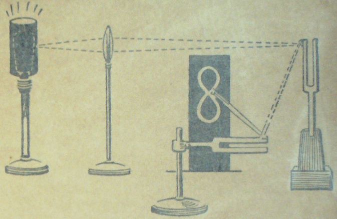


Fig. 47. Lissajous' figures.

Another way of observing Lissajous' figures, which requires slightly more apparatus, is as follows. Surround a lamp with black cardboard in which there is a pin-hole, this will give you a small ray of light (Fig. 47). Bring it to a focus by means of a convex lens supported on a stand and at the focus place a tuning fork so that the light plays on a tiny fragment of mirror which you have secured to the end of one arm. The light will be reflected at an angle, and a few inches away you should put another tuning fork, supported horizontally, so that a mirror on the arm throws the light on to a screen. Now switch out the light and you are ready for action. Start the forks vibrating and you will see the figure of eight, or a variation of it, on the screen. The exact form of the figure will depend, of course, on the relationship between the two tuning forks; a "simple" relationship will give you a simple figure. A more complicated ratio will produce one of the variations. If you set one tuning fork vibrating and not the other, you will see a straight line or thin oval. It is only when the two are vibrating together that the figure of eight appears.

Another comparable experiment is the Chladni figure test, in which fine sand is sprinkled upon a flat plate which is held firmly at the centre. When this plate is set into oscillation by stroking the edge with a violin bow, the sand arranges itself in figures which indicate the nodes and anti-nodes upon the plate. The movements of tuning fork prongs are easily compared by attaching a light stylus to one "leg" and touching lightly on a piece of smoked glass.

The Eidophone.—This is a scientific device which, with the help of some light powder, will also give records of sound waves. You can make a simple eidophone out of a few things that are not difficult to get. First of all you will want a small tin saucepan, choosing one with a hollow handle. Remove the cap of tin at the end of the handle with a tin opener and then bore a hole at the point where the handle joins the saucepan. In this way you will have a tube from the end of what was the handle to the inside of the pan. Now get a tin funnel to fit into the hollow handle. Cut a piece of thin rubber from an old balloon. This must be large enough to rather more than go right over the top of the saucepan. Stretch the rubber well and tie it into position securely with thin string. You will now want some fine powder, and this you can get from a chemist. Lycopodium powder, which is really the spores of a club moss, will do well, or you might use precipitated chalk, or tooth powder. At any rate, a little of the powder will cost you only a penny or so. Sprinkle a thin layer of the powder on the sheet of rubber and then sing one clear note, rather loudly, down the funnel. You will be pleased to see that the grains of powder arrange themselves in a pattern on the rubber sheet. Vary the note and you will get a different pattern, and so you can go on getting a great deal of amusement from the interesting designs which are formed by the sound vibrations.

Echoes.—Sound is reflected by the denser substances. Everyone is familiar with the "echo" produced when you shout at some distance from a wall or cliff, and with the rolling reflections of thunder from banks of cloud. Of course, the echo is there even when you are quite close to a wall, but it cannot be heard because the original sound and echo strike the ear almost simultaneously. An interesting experiment with echoes, which can be performed indoors, is the reflection of sound by a flame.

The flame should be a gas "fish-tail" that is broad and thin. Place two cardboard tubes, as long as you can get, so that two ends, one of each tube, lie at right angles to each other. Separate them with a sheet of newspaper or large book. Then place a watch at the "free" end of one tube, and your ear at the "free" end of the other. You will not hear the watch ticking, or, if you have very sharp ears, only very faintly. But if you now bring your fish-tail flame so that it forms an angle of forty-five degrees to the ends of the tubes close together, you will hear the watch ticking quite distinctly, as the sound is reflected by the flame.

The "Sensitive Flame."—Amusing experiments can be performed with a "sensitive flame." To make this, draw out a piece of glass tubing to a jet, about one-sixteenth of an inch in diameter. If you connect up with rubber tubing to the gas, you will get a long thin flame. The flame is at its best when the gas pressure is at its highest or most regular point. A football bladder in series with the pipe helps to steady variations in the mains supply.

If you sound a whistle near the flame, it will dip and spread out. The dipping in response to the sound vibrations makes the flame more luminous and you can try an amusing trick on a friend. Ask him to read by the sensitive flame, he will probably be unable to do so, as it gives a very bad light. But if you whistle, the flame will spread out and he will be able to see to read quite easily.

Some years ago a burglar alarm based on this sensitive flame was invented. When a noise was made, the flame dipped and heated a strip of two metals welded together. The metals, of course, expanded unequally, so that the strip bent and connected up a battery and bell circuit. To-day a similar alarm could be better and more economically constructed with a microphone.

The reason why a sensitive flame dips in response to a sound is that it is arranged to be on the point of "roaring." A little more pressure then pushes it "over the edge." The sound waves strike the flame, pushing it over. This principle has actually been used to search out certain obscure noises in machinery.

The "Singing Flame."—If in the course of the chemical experiments I describe you should make hydrogen, it is well worth while trying to make a flame "sing." Having made sure that there is no air in the pipe from which the hydrogen is coming, light the jet. If you now place a tube over the flame, it will emit a singing note. The reason is believed to be the heating and cooling of the air, which produces a vibrating column. The note given out from any pipe is the same as that which would be emitted if the air were oscillated in the ordinary way, as in the case of an organ.

How Sound Travels.—Sound travels not only in air and other gases, but also in liquids and solids. Generally speaking, it travels better in liquids and solids. You must have noticed that when you have shouted from a boat, the sound travels a long way over the water. During the war, underwater microphones were able to pick up the

sound of a propeller a considerable distance away; in fact, hydrophones became one of the best weapons against the submarine.

The Toy Telephone.—Sound usually travels very well in solids. If you lay a watch on the table and place a long thin iron bar against it, you will be able to hear the watch ticking very distinctly if you hold your ear against the other end of the rod. Toy "telephones" depend on sound travelling along a thin wire or taut piece of cotton. This telephone is very simply made. Two small cardboard cylinders, about two inches in diameter and two inches deep, are covered at one end with a piece of tissue paper, which is stretched tight and pasted down to form a drum. In the centre of each drum a hole is pierced and the end of a cotton or wire inserted and held in place by tying it to a small piece of match-stick. If the cotton or wire is now stretched taut between the drums, one can be used as an earpiece and the other as a mouthpiece, and a conversation carried on in a whisper can be heard at a considerable distance.

The power of solids to transmit sound can be made the basis of some amusing demonstrations. For instance, you can place one end of the sound rod on a gramophone or wireless set and the other end upon the strings of a violin. If possible, have the violin in another room where the sound of the gramophone cannot be heard. If you now put on a record of a violin playing, the violin will reproduce the notes, rather faintly, but quite distinctly. If a human voice is singing, the violin will reproduce some of the notes better than others, but you will be able to recognize the tune.

"The Phantom Orchestra."—This is a more elaborate version of the previous trick. It is a striking stage illusion and can be produced on a small scale by the amateur. On the stage is a set of instruments, lying on the chairs, and no musicians are visible. By means of hidden rods, these instruments are connected to another set hidden behind a curtain. When the concealed instruments are played, the others give a subdued rendering of the piece. If very long rods are used, all kinds of weird effects can be noticed. The speed of sound through solid material is higher than in air. For this reason guns can sometimes be heard "twice."

Sound travels through the bones of the head; in fact, we all hear to some degree through these bones. Thomas Edison, who for many years before his death was deaf, could only hear a gramophone record through his teeth. If you have an old record and strong teeth, you can try this for yourself. Hold the needle firmly in the groove, and although you will not hear a sound through your ears and nobody else in the room will be aware that the machine is playing, you will hear the record. It is for this reason that the placing of cotton-wool in the ears gives but little protection against noise, it is still transmitted through the bones of the head. Be careful not to swallow the needle.

A very sensational "silent orchestra" can be made by transmitting music inductively to coils of wire connected to headphones and carried by the listener.

If you have ever had a loudspeaker working in a room in which there is a piano, you may have noticed that every now and then the piano gives out a faint note in "sympathy." The sound waves travel across the room and vibrate those strings that are tuned to the same wave length, making them emit a note. Some men with very powerful and well-controlled voices are said to be able to crack a wine glass with a single note, while we all know that sound can cause "concussion" and break a window pane. The sound of a gun a mile away can make the windows rattle, although the actual energy radiated from a large band is usually less than that from a burning safety match when expressed in terms of heat.

Opening the Door with a Whistle.—The response of solid bodies to sound vibration can be made use of in a very striking experiment in which a door opens in response to a whistle. A little care is necessary in construction, but the broad details are as follows. I have actually arranged similar apparatus to open an ordinary door, but it is safer at first to try a small door in a model doll's house.

First of all make sure that your door moves very easily on well-oiled hinges, as you will have no energy to spare. Now down the side of the door stretch a banjo string between two strings, so that you can loosen or tighten it as required. A small fraction of an inch from the string place a terminal, so that when the wire is plucked it strikes the terminal. From this terminal a wire leads to a small electro-magnet like that used in electric door bells. A wire from one of the screws holding the banjo wire leads to a battery and then on to the other terminal of the electro-magnet. Thus you will see that your banjo wire is really a switch, and when vibrated, closes the circuit bringing the electro-magnet into action.

Screw the electro-magnet inside the box or house, so that it is a fraction of an inch from the inner edge of the door when open, and opposite fix a small iron "contact." If you now sound a whistle, the string will vibrate. If it fails to respond, try tightening it until it sounds much the same note as the whistle. The vibration of the string will close up the circuit and bring the electro-magnet into action so that the metal is attracted and the door closed. If there does not seem to be sufficient power in the electro-magnet, weight the bottom of the door, so that the slightest pull will close it.

"Sympathy" in Vibration.—Two tuning forks of the same pitch will show the same "sympathy" as the string and whistle. If you set up two forks of, say 500 and 400 vibrations a second, at one end of the room, and one of 400 at the other, you will find that the 400 fork will respond to a sound from the other end, but the 500 will remain silent when the tuning fork at the opposite end of the room is sounded.

Waves of different pitch may mingle and interfere with one another. If you draw on a piece of paper a wave representing 500 vibrations a second and another representing 505 a second, you will find that after a certain time, the crest of one wave coincides exactly with the trough of another. This means that the loudness of the sound is greatly increased at this point, and so you will have a rhythmic increasing and decreasing of the intensity of the sound. There will also be curious silences, and if you count the number of silences, you will be able to tell the relative values of the two forks. For instance, suppose you count thirty-two silences in eight seconds, you will know that there are four in one second and that the difference in vibration between the two forks is four vibrations a second. Thus if one fork is 500 per second, the other will be 504.

If you have no tuning forks, you can perform this experiment with two wine glasses filled with water. Adjust the amount of water in one of them until it gives out a note slightly higher than the other when rubbed with a moistened finger. Now get a friend to rub one glass while you rub the other, and you will be able to hear the "beats" of the two waves. This matter may be of considerable interest in life, and I remember reading of an Australian being acquitted of a serious crime because an acoustical expert was able to show that he was standing in a zone of silence and could not have heard shouts for help.

Even an ordinary piano will show the sympathy of vibrating strings. Press down a high note and keep the key pressed down. Then sound the octave lower down and stifle it quickly with the pedal. You will hear the higher note sounding in sympathy. In this case, of course, the two strings were not giving the same "fundamental" note, but the lower note contains the upper octave as an "overtone" and, therefore, the higher string sounds in sympathy. You can see a violinist producing overtones, those apparently high, æthereal notes, by touching the string lightly with his finger half-way between the point at which it is stopped and the bridge.

The Tubaphone and the Xylophone.—A number of more or less musical instruments are easily made at home. One of the simplest is the tubaphone, of which elaborate forms are frequently played on the stage. For this you can use tubes of cardboard, which have to be cut to lengths growing shorter and shorter. The shorter the tube, of course, the higher the note, because the greater the number of vibrations a second.

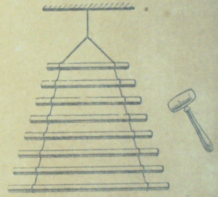


FIG. 48. THE TUBAPHONE.

Presuming that you use cardboard tubing of the same diameter for each note, to obtain the octave you should cut the lengths as follows (Fig. 48). The longest tube should be 45 inches, the next 40, and then the notes in the ascending scale will be 36, $33\frac{3}{4}$, 30, 27, 24 and $22\frac{1}{2}$. If you cannot find cardboard of this length, you can start with any length you like, as long as you make the other tubes in the same proportionate length. This gives you the scale of C; sharps and flats can be inserted by putting proportionate half-tones.

Tie these tubes together with fine thread and hang them up. A hammer for striking the tubes is easily made by inserting a handle in a cork. Wooden rods may be used instead of cardboard tubes, and the harder the wood, the better. These wooden instruments are called "xylophones," and although they are mostly found on the music-hall stage, they occasionally appear in the classical orchestra.

The tubaphone and xylophone are "percussion" instruments, that is to say, as with the drum and cymbals, the vibrations are started by the act of striking. In other instruments, such as the whistle, the oscillations are created by the vibration of a reed or thin piece of metal when blown upon. In the stringed group of instruments, the vibrations are set up by bowing, resin being used to give the horsehair bow a grip.

Violin from a Cigar Box.—A very simple stringed instrument can be made from a cigar box (Fig. 49). With a fret-saw cut out two S-shaped figures in the lid, and then glue it down securely. All paper should be removed and a long wooden handle should be screwed firmly to the lid. Now you require only a screw at the upper end of the "handle," another at the extreme end of the box, a simple "bridge" of thin wood, and you are ready. Twist the ends of a banjo string to the screws, and tighten them over the bridge. You will be able to produce notes by bowing the string, and by pressing your finger firmly on the string against the handle, obtain almost any note in the scale.

The "Moaning Rod."—Another instrument which is rather less, than more, musical is a "moaning rod" which, if you are interested in theatricals, will give an excellent "sound effect" of the wind moaning in the chimney pots. The instrument is very simply made. A hole in a piece

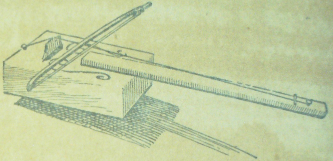


FIG. 49. A SIMPLE STRINGED INSTRUMENT MADE FROM A CIGAR BOX.

of long thin wood or a ruler, a piece of string knotted through the hole and you are ready. The instrument is "played" by whirling the ruler round and round on the end of the string.

If you look at someone whirling this instrument round, you will notice that you appear to see the ruler lying flat. Actually, it is twisting round and round, and after a little you will find the string very twisted. The reason why it appears flat is, of course, the persistence of vision. You see a number of very rapid "pictures" of the flat ruler, and your eye carries the image for a sufficient length of time to make it appear continuous.

The Telephonic String.—Make a loop two feet long at one end of a piece of string (about six feet in length); at the other end a loop just large enough to take a lead pencil. Get a member of the audience to cover his ears with the palms of his hands, place the large loop over his head and hands, and draw the other end, which contains the pencil, tight. With a thumb and first finger at either end of the pencil, gently turn it round. This action will seem to the person holding the string like the sound of guns firing. Other curious effects, such as thunder, the firing of heavy guns, waves, etc., will be obtained if the back of a knife, or a piece of paper folded over, is rubbed gently along the string. Flicking the string will produce a heavy roll like the booming of a big gun. The string should be kept taut the whole time.

Another similar experiment is to take a spoon or poker and tie the middle of a couple of yards of string to the handle. Twist the first finger of each hand in the ends of the string, and then put your fingers in your ears. Gently knock the spoon against the edge of a table or some other object and you will hear the sound apparently greatly magnified. With luck, you will hear a long continuous note not unlike that of an organ pipe.

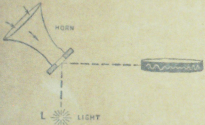


Fig. 50. A model Audiometer (1).

As I have already explained, a number of notes cannot be heard by human ears, although they may have great effect upon the nervous system. In some modern buildings many noises are absorbed by finding out the right kind of material and covering the chief sources of reflection with "mattresses" or special plaster.

A Model Audiometer.—There are several methods of recording echoes and of photographing sound, but a simple apparatus can be made to draw the waves of the voice and those of many musical instruments. The principle of an audiometer is very simple (Fig. 50). A light is thrown from a powerful bulb, or an arc, on to a small mirror platinized on to the surface of a celluloid diaphragm. It is then reflected on to a travelling strip of film and a lens system is used to provide for focussing. When the sounds strike the diaphragm from the horn, the mirror moves in accordance with the changes of air pressure and tilts the beam of light so that a curve is traced on the film. Ordinary mechanical arrangements are made for exposing different parts of the films as may be required, and in the case of optical examination alone, a line of light instead of a spot is thrown on a strip of black paper on which wide vertical lines are printed. Owing to the persistence of vision, this enables the actual wave form to be seen before a permanent record is made.

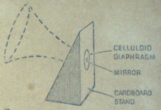


Fig. 51. A model Audiometer (2).

Quite an effective model can be made by preparing a cardboard stand as shown in Fig. 51 and by covering the hole with a thin celluloid diaphragm. To make this diaphragm a solution of celluloid in amyl acetate is prepared, or accumulator repairing cement can be used. One drop is allowed to fall on a bowl of water, when it will immediately spread out and will often show iridescent colours due to the separation of the white light into its component colours. A loop of wire is then slipped into the water and lifted out carefully, carrying with it the diaphragm, which can then be pressed gently against a rim of glue laid round the hole in the cardboard stand. By suspending a drum (Fig. 52), upon which the necessary lines have been ruled, and by using a slot in connection with a lens from an ordinary pocket flash torch, a beam of light is projected on to the disc while the latter is spun round by blowing on the rim.

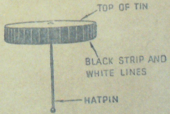


Fig. 52. A model Audiometer (3.)

As soon as sound is allowed to enter the trumpet, the wave shape of the record can be seen. Such diagrams are very interesting, for they not only enable music to be examined, but they can help to locate acoustical faults in buildings or to analyse the many stray sounds which so seriously waste physical and mental energy in our everyday life.

The Watch Dog.—A very interesting toy can be made from a cardboard box at the back of which is fitted a thin tin diaphragm. If an elastic band is fixed inside the box so that when a small wooden dog is pushed into the case the band is stretched, "Fido" can be made to jump out when the correct note is whistled. A catch is attached to the rear of the dog or is stuck to the diaphragm by means of wax. As soon as the thin tin is vibrated by the sound, the catch or wax is released, and out comes the dog.

EXPERIMENTS IN PHYSICS

CHAPTER V

EXPERIMENTS IN PHYSICS

EINSTEIN may have taught us that gravity is a relationship rather than a force, but it will be many years before the convenient phrase "the force of gravity" and "centre of gravity" fall into disuse. We are dependent upon the centre of gravity almost every second of the day; indeed, we should have a very amusing time if we suddenly lost our sense of its position in regard to our own bodies. Most people have tried the old trick of standing with the back of the heels against a wall and trying to touch the toes. The victim falls over forwards because the wall prevents the necessary adjustment of the position of the centre of gravity and Nature takes the easiest way out by "pushing" him on to the floor, where his centre of gravity will not be disturbed! If you try to touch your toes in the middle of the room, you should find no difficulty, because the balance is kept by pushing the back out to balance the forward movement of the trunk.

EXPERIMENTS WITH GRAVITY

Many remarkable tricks can be performed with simple apparatus to show the position of the centre of gravity in a system of weights. Some years ago these experiments used to be popular substitutes for after-dinner speeches, which explains why so many of them make use of bottles, corks, and forks!

If you push two forks into opposite sides of a cork, you will be able to balance them on the upper rim of a bottle which is slightly tilted. Provided the centre of gravity of the cork and forks is exactly over the bottle, you can tip the bottle until it is almost horizontal.

A still more curious experiment is to stick a pin into the bottom of the same cork and to place some heavy object on top. The pin can then be balanced on a coin lying over the mouth of the bottle, and by giving the forks a gentle push, the whole apparatus can be made to spin without upsetting.

Juggling and Balancing Feats.—The scientific use of the "centre of gravity" is demonstrated to perfection by the juggler, who by constant practice has accustomed himself to almost instantaneous and automatic adjustment, so that he can perform feats which seem quite uncanny. He does nothing unnatural, but rather observes perfectly the natural laws. The amateur can only hope to attain this efficiency by hours, days, and even years of practice, but there are several feats he can perform very easily.

If you can secure a quiet room where there is not a breath of air, you may be able to balance one egg on top of another. You will need to sit down and be careful not to breath upon the eggs; in fact, the experiment is hardly worth performing except to convince yourself that there is nothing in the world which cannot be balanced on something else. It is easy to work out the point of balance theoretically, it is not quite so simple to make the adjustments in practice. But I believe that one man has succeeded in balancing three eggs one on top of the other for three minutes!

Many popular mechanical toys depend for their action upon the correct use of gravity. There used to be one in which two puppets coupled by horizontal bars, representing arms, swung each other down a flight of miniature steps. These toys are not easy to make, but here are two experiments which are more startling. The first consists in achieving the seemingly impossible, making a ring run uphill.

Making a Ring Run Uphill.—Prepare your ring of stiff paper and make it about a foot or eighteen inches in diameter (Fig. 53). Inside the ring stick a small lump of lead, a small piece of sealing wax or some other weight. Prepare an uphill run for the ring by supporting a smooth board at one end. Now place your ring in position at the bottom, with the weight on top and a trifle nearer to the top of the hill than the point on which the ring rests. If you let go the ring, it will appear to roll up the board. The weight pulls the ring round, attempting to bring the centre of gravity over the point of support.

Even more striking is the double cone which rolls uphill. You may have a double cone, used as a model for drawing, if not, make one by sticking two paper cones together at their bases. Arrange an inclined plane by placing two broomsticks over two piles of books, one higher than the other. Lay the broomsticks so that they are not parallel but closer together at the lower, than at the upper, end. When you put the cone on the lower portion of the sticks, it will appear to roll up towards the higher end. If this does not happen immediately, move the sticks a little further apart or nearer together. Actually, of course, the cone does not climb, but falls lower

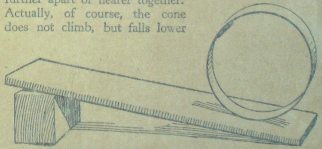


FIG. 53. MAKING A RING RUN UPHILL.

and lower between the "rails," thus giving the illusion of upward movement.

A Seemingly "Impossible" Trick.—These experiments illustrate an important rule of mechanics—that all bodies tend to move so that their centre of gravity is in the lowest possible position. If you remember this, many balancing feats become possible. Here is one which when described brings forth the word "Impossible," yet is not really at all difficult (Fig. 54).

You need a key, one of the old-fashioned kind with a hollow end, a couple of nails, a long piece of wood and a heavy weight. First attach the key to the wood, by inserting the nail, which must be bent, and tying its head tightly round the bar of wood. Next drive the point of the other nail just into the table top, the kitchen table is safest! and, finally, tie the weight to the other end of the wood. With a little patience you will be able to make the handle of the key, supporting the wooden bar and weight, balance on the head of the nail. It sounds impossible, but the weight tends to swing under the table, that is, under the point of suspension, and you will find a balance when the centre of gravity is exactly beneath the point of suspension.

To Balance a Cigar on the Tip of a Finger.—Fix the point of the blade of a penknife into the tip of a cigar at an angle which makes the handle of the knife act as a balance, then place the tip of the cigar on the finger, and the cigar will stand perfectly upright.

Balancing Birds.—There is a popular toy in which a small wooden bird, usually a parrot, balances on the end of the finger. In the case of the celluloid parrot, the tail curls under the body and is filled with lead shot. Here again, the centre of gravity rapidly swings under the point of suspension, and it is possible to give the bird a hard push without dislodging it from the perch.

Any small toy birds you may happen to have, or be able

to purchase for a few pence, may be made to "perch" in the same way quite simply. Cut about three or four inches, according to the size of the bird, from a coil of stiff iron wire. Fix one end firmly in the body of the bird, behind its feet, and carrying it straight down, turn the wire up in a small hook. On this hook fix a weight, a ball of sealing wax is convenient, as you can adjust the amount. This bird should now balance on your finger, the weight being exactly beneath the point of suspension, although you may have to adjust the wire a little to achieve this position.

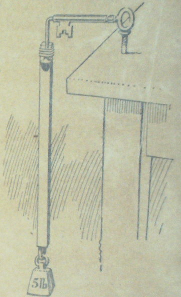


FIG. 54. A SEEMINGLY "IMPOSSIBLE" TRICK.

A simple candlestick, which is especially useful for Christmas trees, can be constructed on the same principle. The difficulty with candles on Christmas trees is usually to prevent them tipping over and burning unevenly. If you prepare your wire with a small weight as before and give the other end a double bend so that it is like a horizontal "S," you can stick the point in the bottom of the candle and hang the whole by the bend in the wire. However much a draught may make the branches of the tree sway, the candle will always remain upright.

The Man and the Saw.—One of the balancing models that used to be sold in the streets was a puppet which

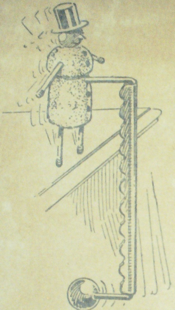


FIG. 55. THE MAN AND THE SAW.

apparently spent its life in sawing the edges of the table (Fig. 55). Let me assure you that if you make this simple puppet, there will be no need to damage your best polished dining table! The man can be made out of cork—a champagne cork will give the effect of a body and chest. His head may be moulded out of putty or sealing wax and attached by using a match stick for a "neck." Two matches with the heads burned off make the legs and two other matches, the arms, which stick straight out in front. Now you have a puppet that resembles a human being slightly, but the more grotesque he is the better.

The saw is made by bending a piece of wire twice at right angles and attaching to the middle portion one of those pieces of serrated metal used in making cardboard boxes. Now push one of the long handles into the body of the puppet, level with his arms, and the other into a weight; a small apple will do. Place the puppet on the edge of the table so that the saw carries the weight underneath him, and you will be able to set the figure rocking on its match-stick legs, so that it appears to be sawing through the table. An amusing variation is to insert the saw in the puppet's back and then invite your audience to look at him from the other end of the table. As he swings pre-

NAWAB SALAR JUNG BAHADUR

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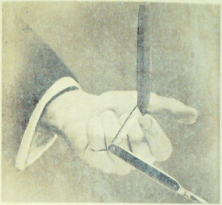
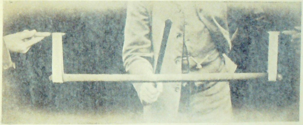
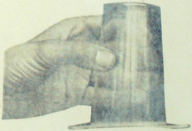


1. Balancing a cigar on the tip of the finger. (See page 142.)



2. Breaking a broomstick. (See page 142.)



3. The inverted tumbler. (See page 159.)

cariously backwards, everyone will expect him to tumble off, but his centre of gravity will come to the rescue and prevent this disaster!

The Candle See-Saw.—The see-saw is, of course, a long plank of wood supported by a rod through its centre of gravity, the wood moving up and down when the centre of gravity is moved. An amusing see-saw can be made with a knitting needle and a candle (Fig. 56). Heat the knitting needle and push it through the centre of the candle. Support the ends of the knitting needle and place a saucer under each end of the candle. Now light the wick at both ends of the candle and very soon it will start a rocking up and down movement. You will see, of course, why this happens. When a drop of melted grease falls from one end, the other end becomes the heavier, and this part tries to get under the point of suspension. Then a drip falls away, and the other side becomes the heavier, and so on.

The Balancing Egg.—Yet another experiment with gravity that provides endless amusement. "Blow" a hen's egg by making a hole at each end. Then wash it clean and pour in a little fine sand to fill about one-quarter of the empty space. Seal the holes with a little wax and you are ready. The egg will, apparently, do anything you like, and will puzzle those who do not know its peculiar construction. This egg will balance on end in almost any position, even on the edge of a bottle mouth or a knife, it will stand upright on either end or on its side. If anyone should dare to suggest that your egg is "faked" in some way, offer to let them try to balance it. They could, of course, imitate all your own tricks, but you pass over another egg which contains, instead of sand, a small piece of lead stuck to the bottom with wax. This egg will refuse to do anything but stand on end!

What is the "Centre of Gravity"?—After all these experiments, you may want to know exactly what is the "centre of gravity." It is difficult to give a simple yet accurate definition, but a good working one is "the point at which a body, acted upon only by gravity, will balance itself in all positions. As long as the centre of gravity is supported, the body cannot fall. That is why the famous leaning towers of the world are, theoretically at any rate, perfectly safe. The centre of gravity falls within the base.

To Lift a Man with Five Fingers.—One final experiment to show the equal subdivision of weight. Two persons put their index fingers under the insteps of the person who is to be lifted, two others place a finger under each elbow, and a fifth puts his forefinger under the chin of the subject. At a given signal each person lifts his hand, and the person is raised up. The result may seem very surprising, but it is only a question of the equal subdivision of the pull of gravity. The average human being weighs about eleven stone, so that each finger has only to sustain about thirty pounds weight, which is not difficult.

EXPERIMENTS WITH PENDULUMS

One of the most useful applications of the force of gravity, without which we should not have wrist watches and grandfather clocks, is the pendulum. When the bob of the pendulum reaches its highest point, the force of gravity pulls it down and swings it up to the other side. Gradually, of course, the beats get shorter and shorter, but as long as the length of the pendulum is unaltered, the beat will always take exactly the same time, regardless of whether the bob barely moves, or swings almost horizontally. It is this fact which makes the pendulum, or its spring counterpart, so useful in clocks and watches. Indeed, until electrical methods of measurement were discovered recently, the pendulum was our most reliable timing device.

The balance wheel of a watch is simply another form of the pendulum, and the rate of swing depends, to a degree on the position of the pendulum with reference to the equator. For instance, in London a pendulum has to be 3.262 feet in length to have a beat of one second, but in other parts of the world, the length would be more or less than this figure.

Harmonic Motion of Two Pendulums.—It is interesting to compare the patterns produced by connected or plain pendulums with the patterns obtained from the vibrations of two tuning forks of different pitch. The simplest form of apparatus for demonstrating the harmonic motion of two pendulums consists of a conical bag filled with sand or flour which can trickle very slowly out of the bottom (Fig. 57).

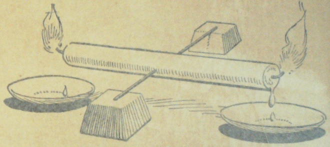


Fig. 56. The candle see-saw.

The bag is tied to a length of string, which half-way up is divided into two. Now suspend the bag by the two ends of the string and set it swinging. It will make a simple straight line up and down, the flour or sand tracing the course on the floor. But if you give the pendulum a double swing, so that the double strings swing one way and the single string in a direction at right angles, you will find that the flour bag is marking out a figure of eight

A more permanent record of this "harmonic motion" can be obtained with a slightly more elaborate piece of apparatus, which will give an endless variety of patterns. First you require two pendulums. These should be of metal, and if you cannot obtain two ready made, you can construct them quite easily out of curtain rods, simply affixing a weight to one end and boring a hole at the other to allow of suspension. The weights on the ends should, if possible, be movable, so that the length of the pendulum can be altered as required.

Now make a wooden holder for the pendulums so that they swing at right angles to each other. On to one pendulum fix an arm, the long end of which holds a pen nib and the other end of which balances it with a weight. On the top of the other pendulum, you should fix a small piece of light wood, forming a flat table on to which you can pin a piece of drawing paper to receive the pattern.

If you start the pendulums rocking and bring the nib down so that it just touches the paper, you will soon find that a most elaborate pattern is being traced and at the end of a quarter of an hour, you will have a remarkable design. If you experiment with your pendulums, you will discover several interesting facts. For instance, if you have the pendulums of exactly the same length and start them moving at exactly the same moment, your pen will trace only a simple circle. By altering the lengths and the relative times of starting or "phase," you will have the opportunity of making an endless series of different designs.

A better plan than using a simple nib dipped in ink, is to employ an old fountain pen, while if you wish for a striking result, you can use one of the invisible inks which I shall describe, so that your pattern does not appear at all until it is developed. Yet another alternative is to use a fine needle and in place of paper, a piece of smoked glass. The pattern will then be traced as a number of fine white lines that can be printed photographically. This apparatus is sometimes called a "harmonograph."

Goold's Dancing Pendulums.—Some time ago an experimenter named Goold made a very interesting piece of apparatus with two pendulums, and this is worth copying because of the peculiar effects produced. In their simplest form, Goold's pendulums require a wooden lath of fairly springy wood and about two feet in length. Support the lath on the backs of two chairs and about two feet off the ground. Into the lath, at equal distances from the ends and from each other, screw two small hooks, and attach two little spiral springs. Finally, on to the springs fix about a foot of thin chain, at the ends of which are supported two weights.

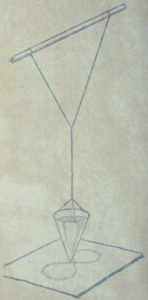


FIG. 57. HARMONIC MOTION OF TWO PENDULUMS.

Now you can demonstrate how matter, as well as mind, can communicate! If you start one pendulum vibrating by giving it a pull so that it dances up and down, and watch carefully, you will see the other pendulum gradually join in the dance. As soon as the second pendulum comes into action, the first comes to rest, but in a few seconds, the first pendulum will again take up the rhythm and the second will stop. This will continue for a long time, each pendulum doing a sort of dance and then taking a rest while the other dances, but never will they dance together!

The swing of pendulums can be communicated in the same way and for this experiment you will not require springs. Suspend your weights by pieces of string, and loop the strings round a light wooden rod, about half-way up. If you swing one pendulum, the other will imitate it. Now if you lower the wooden rod, so that it is only one-quarter the way up the string, instead of half-way up, you will find that the change comes about much more quickly; indeed, you can bring the rod almost down to the weights so that they swing only once each.

Foucault's Pendulum.—Finally, here is an amusing after-dinner trick with a pendulum. Construct your pendulum with three forks with their points stuck into a cork so that they form a tripod. Balance this tripod on a large plate and suspend a small pendulum from the top. A good pendulum can be made of a cherry through which a match stick has been passed. The string is attached to one end of the stick, while the other projects slightly beyond the cherry.

Set the pendulum swinging and at each end of the swing make a small pile of salt so that the end of the match just cuts it, leaving a mark in it. As long as you do not touch the plate, the pendulum will swing over the same marks over and over again. But if you now move the plate slowly round without touching the pendulum, you will find that the pendulum continues to swing in the same plane so that it makes new marks in the salt. This experiment was first performed by Foucault eighty years ago, hence the pendulum is called a "Foucault pendulum." The experiment demonstrates that the earth revolves round its polar axis, as you will see if you think for a minute or two.

INERTIA AND MOMENTUM

All bodies have what we call inertia—a certain resistance to motion. If you push a heavy object, such as a large stone, you know that it takes more effort to start it than to keep it moving. That is why cart horses have to strain and tug when starting with a heavy load, and why a railway carriage which can be kept moving by one man fairly easily on the level, takes a considerable push to start it. If it were not for inertia, life would be very complicated. If inertia did not exist and you brushed against the chest of drawers, it would shoot to the opposite side of the room and if you pushed a man, he might go back five yards! On the other hand, road accidents would not, perhaps, be so serious, for in a collision between a car and a walker the unfortunate pedestrian would be shot twenty yards, or more, down the road!

One of Newton's laws tells us that the resistance of a body is always equal to the force applied, so that when you place a book on the table, the table pushes the book with the same force that the book pushes the table. In other words, the book remains inert.

When two forces act on a body at the same time, the body takes a direction known as a "resultant." This law explains the movement of the planets and the stars. To overcome inertia a force greater than that of the inert body is required and this force sometimes has to be surprisingly strong. This suggests a number of experiments which may literally be called "very striking."

You know that if you place a number of pennies in a row on the table, so that they are touching each other, and push the penny at one end, the force is communicated through the row, so that the penny at the other end is also pushed along the table. The force is communicated from penny to penny, but it takes an appreciable time to act. You can prove this on a bigger scale by a remarkable experiment requiring a little courage and a certain amount of faith in the laws of mechanics.

The Broomstick and the Tumblers.—Place two chairs with the seats towards each other, and set them the length of a broomstick apart. On the chairs put two glasses of water and into the ends of the broomstick push a needle firmly, so that you can lift the broomstick by the needles. Finally, balance the needles on the glasses so that the broomstick is supported. Now you are ready to begin.

Taking up a position in the centre of the broomstick, give it a good strong blow with a poker. The broomstick will smash into two or more pieces, but not a drop of water will be spilt! You must strike the broomstick boldly and really hard. If you are half hearted and have no confidence in the trick, the force will have time to reach the needles and the glasses before the broomstick breaks, and you will probably lose two good tumblers and make a mess on the carpet! This is a modern and safe version of an old swordsman's trick. You can often cut a pencil in half with a piece of stiff folded paper if the blow is sufficiently quick.

A simpler way of illustrating the same effect is to take a heavy piece of wood and tie pieces of wool or thread to both ends. Suspend the wood by one of the threads and then give the other a sharp tug. It will break underneath the wood. In spite of the weight on the upper thread, the lower one breaks first because of the inertia of the wood. If you give a steady pull instead of a sharp one, it will break above the wood, because of the additional weight, which is given time to come into action.

The Sixpence and the Ring.—A large number of "Parlour Tricks" are based on the "phenomenon" of inertia. For instance, if you have the paper ring which rolled uphill (page 141), it can be used for a good trick. Place it upright over the mouth of a wide-necked bottle or jar; a bottle makes the trick more striking. On top of the paper ring, put a sixpence, so that it is exactly over the mouth of the bottle. Hold a ruler with one end inside the middle of the ring and suddenly give the ring a sharp blow horizontally so that it is knocked away. The sixpence will drop straight down into the bottle with a convincing ring! Your blow was so quick that there was no time for it to be communicated to the coin.

Simple Tricks with Coins.—Even the simple trick of balancing a penny, or pile of pennies if you are skilful, on the bent elbow and then suddenly bringing the hand down to catch it depends on the moment of inertia. Here are two variations of this trick. Tear a long strip of paper and hang it over the edge of the table. Stand a half-crown up on its rim over the end of the paper. Give the paper a sudden blow with a ruler, and it will flutter to the ground, leaving the coin standing on its edge. Alternatively, balance a postcard on your finger and on top place a penny. Now, with your other hand, flip the card away suddenly. The penny will remain balanced on your finger.

Here are a few other tricks based on inertia, one of which is, I think, new, and the others of which are always striking to watch. Place a pile of half-crowns on the table, and taking careful aim with the ruler, give the middle coin a hard blow with the edge. It will fly out from the pile without upsetting the others. This requires practice, and a simpler form is to use draughtsmen, when, if you have a good eye, you can hardly fail to administer a good, clean blow.

The next problem is to "call" a sixpence out of a tumbler. Invert the tumbler over the sixpence and support the rim on two half-crowns so that the sixpence has just room to come out. The problem is to get the sixpence out without touching it or the tumbler. It is easy once you know the secret. Just scratch the table cloth with your first finger and the force will communicate itself through the cloth to the sixpence, which will obediently come out from underneath the glass as the cloth jerks back each time beneath the coin.

If a plate is prepared with a very small needle, about a quarter of an inch long, lying close to the underside and pointing towards the rim, it can be placed on a tablecloth and an audience challenged to move the cloth without touching the plate. A smart jerk to the cloth leaves the plate safely in position; but not if the point of the needle faces away from the experimenter!

The Stone Breaker.—By great acquired force, or inertia in repose, one is enabled to break stones with the fist. This feat is performed by men at fairs in the following manner:—

The right hand is carefully wrapped in a bandage, and in the left is held a piece of flint of rounded form, which the operator places on a larger stone, or upon an anvil; then with the right hand he strikes the flint some very powerful blows, always taking care to raise the stone secretly a little from the anvil when about to strike. Thus the object struck acquires the force of the fist that has struck it, and as it comes in violent contact with the anvil it is quickly broken. Simple as the feat is, it never fails to evoke great astonishment.

To Uncork a Bottle Without a Corkscrew.—Here is another trick that relies upon the principle of inertia for its effectiveness. Fold a dinner napkin into a pad, hold it flat against the wall, and strike the bottom of a bottle of wine, beer, or any other liquid, violently against it. By virtue of the principle of inertia, the liquid in the bottle will force out the cork. If the contents are beer or gaseous water, the cork will come out with considerable force and some of the liquid will shoot over the operator, and so enhance the success of the experiment—from the spectators' point of view.

A Piece of Money Rolling on an Umbrella.—This is a feat performed by nearly all jugglers. An umbrella, usually a Japanese one, is opened, and half-crowns, balls or similar articles are made to circle round the top. The umbrella is turned rapidly round in the opposite direction to that in which the article is set going, and the coins, etc., appear to be running along the surface; in reality it is the umbrella that is moving beneath the articles. This is another example of the principle of inertia.

CENTRIFUGAL FORCE

Another interesting effect is that of centrifugal force, which is extremely important to engineers. If you take a bucket half-full of water and whirl it rapidly round you, the water will not spill, even when the bucket is upside down. This is because the centrifugal force tends to keep the water pressed against the bucket. In the same manner, you can spin a large ring or hoop round a stick which is held vertically. In the ordinary way, if the stick were still, the hoop would fall immediately. A loop of string spun round on the end of a stick will remain in a tight circle.

Here is a somewhat similar experiment. Procure a glass, a piece of string, a third of a tumbler of water, and a third of a tumbler of oil. Tie a piece of thin string round a conical tumbler, so that a long end is left at each side; bring these over the top, and tie about a foot above the glass, i.e. making a handle: fill about one-third of the tumbler with water, and it can then be swung to and fro, or over and over; the water will remain as steady as if it were ice. Then gently pour some oil upon the water until the tumbler is about two-thirds full. Swing the glass again, the oil will remain tranquil, and the water underneath will be violently agitated.

In engineering, this force is used to separate mixtures and ores, the larger pieces naturally going to the outside of the whirling board. In the near future we shall probably hear a great deal about this force in connection with high-speed flying. When an aeroplane makes a fast turn, the tendency is often for the blood to be swung away from the pilot's head to his feet, and this probably explains why high-speed pilots sometimes experience a "black out." This force may prevent man-piloted machines ever turning corners at more than 500 m.p.h. It was estimated that during the recent automobile record-breaking run at Daytona, the centrifugal force exerted on the rim of the tyres was equal to over four tons! That is one reason why tyres sometimes spin off during a high-speed motor car race.

The Spinning Eggs.—An easy experiment to show the working of centrifugal forces in every-day life is to spin a hard-boiled egg and a fresh egg on the table. The hard-boiled egg will spin much longer than the fresh one, but if you suddenly stop them for a second with your hand, you will find that the fresh egg will move round when you have taken your hand away, while the hard-boiled egg will not. The reason is, of course, that the fluid inside the fresh egg spins round with the shell, and when the shell is stopped, the fluid continues to spin; whereas with the cooked egg, the centre is not free to be moved by centrifugal force.

An alternate way of showing this is to slip an india-rubber band round the eggs and hang them up. If you now give them a spin, you will find that the fresh egg responds very sluggishly, while the hard egg twirls and untwirls several times. The fluid in the fresh egg acts as a break, because a certain amount of force is required to pull it round inside the shell.

If you have a weight on the end of a string and twirl it round, you will notice that the faster you twirl, the higher the weight rises, until when you are moving very fast, the string becomes almost parallel with the ground. This is, of course, the result of centrifugal force, and finds a very useful application in the steam engine as a "governor." The governor consists of two balls which are free to move round and round and rise up and down. The device is employed for the automatic control of a valve. When the engine begins to work more rapidly the balls rise and close a valve, so that the engine slows down. This keeps the engine running at a constant speed, independent of ordinary changes in the working load.

To Keep a Penny Revolving in a Lampshade.—In this experiment the lampshade should be one of cardboard, and of the shape commonly seen over billiard tables. It should be held bottom upwards by the right hand clenching the hole at the top. Now, with the left hand, twirl a coin on its edge into the shade, and at the same moment cause the shade to rotate in the right hand in the opposite direction. The coin will roll round and round on its edge without falling.

If the movement of the shade is gradually slackened, the coin will by degrees rotate towards the lower part of the lamp shade; if the speed is augmented, the coin will by degrees ascend the cone. The movement of the coin will continue just as long as the twirling motion of the shade is kept up. The coin is maintained by the action of centrifugal force, and moves in an inclined position similar to that of a rider on a cycle track. With practice two pieces of money can be rolled in the lamp shade at the same time.

The experiment we have described is very easy to perform; only a slight movement of the hand is needed. Although some dexterity is needed in launching the penny into the lamp shade at first, no particular skill on the part of the performer is required.

If a lamp shade is not available, a basin, a pan or a salad bowl may be used, but the cardboard lamp shade is lightest and most handy, and preferable to all other articles.

To Spin an Egg as Long as Required.—Spin a hard-boiled egg on a small wooden tray, and gently move the tray in a small circle in the opposite direction to that in which the egg is spinning. The egg will revolve for an indefinite period.

THE AIR AND GASES

Most people appreciate that gases possess weight in exactly the same fashion as solids and liquids. The air has weight, but we rarely notice it because we are accustomed to its load. The constant exertion of this weight on everything is called atmospheric pressure. At sea level it is about fifteen pounds to the square inch, a considerable weight to carry about always upon our shoulders! If this pressure were suddenly removed, however, we should die, not only from lack of oxygen, but also from want of weight on our bodies which are built to work normally at the pressures between sea level and 10,000 feet. Above that height, as mountain climbers and airmen know, the lessened pressure produces many peculiar effects.

There are many ways in which you can examine the pressure of the air for yourself. One of the best is to take a piece of board about three feet long and a foot wide and balance it on the edge of a table. A slight blow with the fist will knock it over. But take a couple of sheets of newspaper and lay them flat over the part of the board which is on the table and then try to knock the board over with your fist. You will be unable to do so, because the pressure of the air on the newspaper is so great that it balances the force of your blow.

The Parachute.—The weight of the air supports things with large areas compared with their weight. It supports the aeroplane and the parachute. A very simple parachute can be made for use in the garden, the "passenger" being a lump of lead or stone. A handkerchief will serve, or

a special piece of cloth cut in a circle may be used. Attach the stone to the circumference with half a dozen or more pieces of string of equal length. Then roll the parachute into a neat and tight ball, with the string wound round the stone, and throw as high as you can. As soon as it begins to fall, the stone will come down, the parachute will open, and the weight of the air "pressing upwards" will make the load drift slowly to earth.

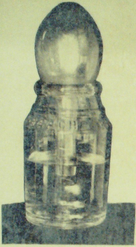
The Inverted Tumblerful of Water.—Another way of showing the upward pressure of air is to take a tumbler and fill it to the brim with water. Place a sheet of stiff paper across the mouth and hold it in position with your left hand. Now, with your right hand grip the tumbler and suddenly invert it. Take your left hand away from the paper, and the water will remain in the tumbler. The upward pressure of the air on the paper is sufficient to overcome the force of gravity which acts on the water, downwards. If there were much air in the tumbler with the water, the experiment would fail.

A variation of this experiment is to use a handkerchief to cover the mouth of the tumbler, which this time is only three-quarters full. While the tumbler is mouth upwards, press the handkerchief in so that the peak just touches the top of the water. Take the corners of the handkerchief firmly in the hand that is holding the tumbler, and invert it. Now carefully tighten the handkerchief until it is stretched taut across the mouth of the tumbler. As you watch you will see the water begin to "boil," air bubbles will rise rapidly to the surface. Actually, of course, this water is not boiling; the air bubbles have been forced up by the upward pressure of the air.

Lifting a Bottle with a Plate.—Here is another experiment showing how the upward pressure of the air will counteract the force of gravity. Hold a bottle over a fire for a few minutes, mouth downwards. Then quickly place a plate over the mouth, and hold it tightly so as to prevent any air from getting into the bottle. After a few minutes the air in the bottle will have cooled. The plate can then be lifted by the edge with the bottle adhering to it. If by any chance the rim of the bottle and the plate are not quite level and there is a possibility of air getting in, a little grease rubbed on the rim of the bottle will overcome the difficulty.

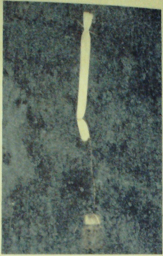
The Magdeburg Hemispheres.—Take two tumblers of the same size, that will fit closely when placed rims together one on top of the other. Light a piece of wax candle, and place it inside the tumbler on the table, cover the top of it with a piece of rather thick paper saturated with water. Turn the other tumbler upside down, and place it upon the one containing the candle. The candle will be extinguished, but while burning it has dilated the air contained in the lower tumbler, and this air has therefore become rarefied. The exterior pressure of the atmosphere will fix the tumblers as closely together as the classical Madgeburg hemispheres are united. It is possible to raise the undermost tumbler by lifting the upper one. The paper may be scorched on the under side, but the success of the experiment is not thereby imperilled.

Making a Hard-boiled Egg Enter a Narrow-necked Bottle.—By means of atmospheric pressure it is possible to make a hard-boiled egg enter a narrow-necked bottle without breaking. Light a piece of paper and plunge it into the bottle. Then place over the neck a hard-boiled egg with the shell removed. The egg will be slowly elongated and will eventually slip right into the bottle. The explanation is simple. The burning paper consumed some of the oxygen and heated the air. When the air cooled, a partial vacuum was formed and the force of the atmosphere, trying to restore the balance or state of equilibrium which is Nature's ideal, pushed the egg into the bottle. Actually, it looks as if the egg is sucked in, but it is really pushed.



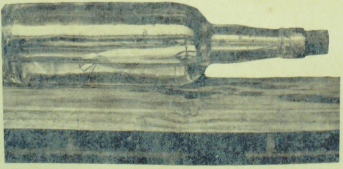
A WATER BAROMETER FORMED FROM AN OIL FLASK AND A JAR.

The water rises or falls in the neck of the bottle according to the air pressure. (See page 165.)



A BOTTLE CANNON.—I.

The contents of the blue packet in a Seidlitz powder are put into a small paper container attached to the cork of the bottle.



A BOTTLE CANNON.—II.

In this experiment one of the packets of a Seidlitz powder is dissolved in a third of a bottle of water. The other packet is attached to the cork, see above. The effervescence blows this out with a loud report. (See page 200.)

We always speak of a vacuum as if it "sucked in," but in reality things are pushed into the vacuum. It is the pressure of the outside air that is the acting force and not the vacuum. The suction of a vacuum is just a convenient way of speaking. If you had a bottle containing small pieces of paper and another "containing" a vacuum, the pieces of paper would be driven into the empty bottle when the mouths of the two bottles were placed together. But if the pieces of paper were first placed in a vacuum, they would remain in position because the atmospheric pressure would be unable to act.

A Coin Held to the Wall by Air Pressure.—Most people have tried the trick of making a penny or half-a-crown stick to the wall by air pressure. You clean the coin, lay it flat against the wall or door and then, after rubbing it firmly up and down for a few seconds, you find that it sticks. By the rubbing process you have excluded the film of air between the coin and the wood, and the pressure of the air keeps it pressed against the wall. If you did not exclude the air, the pressure from the outside would be equal to the pressure inside, and the force of gravity would make the coin fall. The same trick with a pencil is usually successful, but its success is due to the heat of friction melting some of the varnish on the pencil itself.

Lifting a Heavy Weight by a Vacuum.—One of the most interesting experiments that can be performed with a partial vacuum is to cause a heavy weight to be suspended. For this you need a piece of wide glass tubing about a foot long. Fit it with two corks, and through each cork pass a hairpin so that it obtains a good grip of the cork, a small piece of match stick under the hoop will prevent the wire from cutting into the cork. To the hairpins tie pieces of string and insert the corks in the tube so that a piece of string comes out of each end. To one string tie a weight and take the other string in your hand. When you attempt to lift the weight off the ground, the corks will slip apart a little, but will afterwards lift the weight easily. When they are pulled apart, a partial vacuum is created inside the tube, and the pressure of the air enables you to lift the weight, the vacuum becoming almost a "solid" part of the apparatus.

A Glass of Water Suspended by a Thread.—Here is a somewhat similar experiment. Fix one end of a piece of thread with sealing wax or sticking plaster to the centre of the back of a playing card, which must not be penetrated. Hold the card tightly, and quite flat on the top of a tumbler filled to the brim with water, and exclude all air. The glass can then be suspended by the thread and swung pendulum fashion, without the risk of falling.

Atmospheric pressure is more important in every-day life than we imagine. It is by this pressure that the vacuum brakes of our tubes and trains are worked. Air is pumped out of a chamber and the tremendous force of the atmosphere is made to act against the brake, pushing it on to the wheel. It is difficult to realize that this force is so great that it is more powerful than any mechanical lever brake and can draw up an express train weighing hundreds of tons in a minute.

Compressed Air.—The opposite of a vacuum is, of course, compressed air, which is air at a pressure of more than one atmosphere; air which was "compressed" on the top of a high mountain might, if brought down to sea level, become a partial vacuum. In the case of both the vacuum and compressed air, the force of the atmosphere is at work trying to restore the balance, although the natural elasticity of the air also helps in the case of the compression. The pop gun and the modern torpedo are both worked by the compression of air, although efficiency is incre [illegible] n the latter case, by heating the air to prevent th [illegible] g consequent upon expansion.

Tricks with Compressed Air.—You can comp [illegible] air momentarily, by blowing. We all know the force [illegible] the

wind. Here is a trick using momentarily compressed air, but it requires a little practice. Place an egg loosely in an egg cup and just in front of it another empty egg cup. Then blow hard and suddenly, between the egg and the cup, and the egg will jump out. With practice it is possible to make it alight in the other cup; but this, I must confess, does not always succeed!

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A variation which is less expensive is to place a threepenny bit on the table and hold your open hand two or three inches behind it. Aiming a little in front of the coin, blow sharply, and the threepenny bit will suddenly jump up into your waiting hand. The air is compressed by your blowing, and flows underneath the coin, pushing it up.

A small squirt for water can be made quite simply. Half fill a narrow-mouthed bottle with water, and then, placing it to your lips, blow into it hard. Before you take your mouth away, clap the ball of your thumb over the opening. Gradually work your thumb up so that a small hole is made, and the water will squirt out. The air, trying to restore the equilibrium of pressure, forces the water out. With practice the water can be squirted to a considerable distance.

"Suckers."—Some years ago "suckers" used to be very popular toys. They consist of a small piece of soft, moist leather, through the middle of which is passed the end of a string, which is then knotted. The sucker thus made, if pressed firmly against a piece of wood or flat stone and lifted by the string, will raise quite heavy objects. The squeezing process excludes the air from underneath the leather, and when the middle is lifted, the vacuum makes the object cling to the leather. The metal lids of pickle and other preserve bottles are fixed in much the same way, the vacuum in this case being made by driving out the air with steam. When the bottle cools, the steam condenses and leaves a vacuum. The lids can easily be removed by piercing a hole so that the air can enter and restore the natural balance.

The Weight of Air.—Until the middle of the seventeenth century the air was believed to be without weight, but you can prove the fallacy of this for yourself. Place a globe with a stopcock on one arm of a pair of scales and extract the air from the stopcock with a pump. Then balance it with weights, and by turning the stopcock admit the air. The arm with the globe will immediately fall, showing that the air has weight. If you add to the other side to restore the balance and then estimate the volume of air by filling the globe with water from a measuring glass, you will be able to find the exact weight. This will depend, of course, on the temperature of the room and the atmospheric pressure. The higher the temperature and the less the pressure, the lighter the contained air.

A Hot Air or Fire Balloon.—The first balloons were worked by "hot air," which has a not inconsiderable lifting power. Being lighter than air at ordinary temperatures it rises, and can take with it a reasonable extra weight. A small feather dropped above the flame of a candle, for instance, will rise. If you live in the country, you can make a hot-air balloon or "fire balloon," but in a large town, it might be dangerous. Make your balloon of tissue paper, cutting a number of leaf-shaped segments, which when pasted together form a balloon rather long and open at the bottom. Round the base run a piece of light wire with a cross piece. On the cross piece fix a small wad of cotton wool, and and when you are in some open space, pour methylated spirits over the wool and set light to it. The hot air will rise into the balloon and presently it will float up into the air. If it is a good balloon, it will disappear out of sight into the clouds, to be destroyed by a rainstorm or to fall many miles away. These balloons can be made up to six feet in height.

Making a Barometer.—The weight of the air is measured

by the barometer. You can make a water barometer, but you will need a long tube as it will have to be about thirty-five feet high! Mercury is far more convenient. A barometer is very simply made. Fill a tube, about thirty-two inches long, with mercury and then, holding the mouth under a basin of the same liquid, invert the tube so that the mouth is at the bottom. The mercury will fall slightly in the tube until equilibrium is established, but the weight of the air will prevent all the mercury from running out of the tube. The amount that remains shows the weight or pressure of the air.

If you were to mark the position of the mercury in the tube and watched it from day to day, you would see it rise and fall as the atmospheric pressure changed. Moist air weighs less than dry air, hence the mercury falls when rain is about. It is worth mentioning that the space above the mercury is known as the Torricellian vacuum, and is almost a perfect vacuum, containing only minute traces of mercury vapour. Pumps, diving bells, and many other devices in every-day use depend for their action on the weight of air. That is why an ordinary pump will not draw water to a height greater than thirty-one or thirty-two feet.

An Oil and Water Barometer.—One of the sim weather tellers is in the form of a water barome a glass jam jar and about half fill this with in the jar, invert an oil flask from which the rush cov has been removed. You will see that the water rises a little distance in the neck of the bottle. The height of this column of water varies from time to time. When the pressure is high, a state of affairs associated with fine weather, the water in the neck goes up; if the pressure is low, the column of water falls and we may look for rain. Of course, the water in the neck of the bottle rises and falls according to the pressure of the air on the surface of the water in the jar.

The Cartesian Diver.—An amusing toy that can be worked by air pressure is the Cartesian diver, which rises and falls in a bottle of water at the word of command. Weight a small celluloid doll or other figure with lead shot, so that when placed in water, the top of the figure just reaches the surface. Place the figure in a jar full of water and then close the mouth with a piece of rubber sheet, a piece of a toy balloon or inner tube will serve. Tie the rubber down firmly. Now when you press the top, the figure will dive to the bottom, remaining there until the pressure is released. Why is this? When the pressure is normal, the amount of water displaced is such that the figure just stays afloat; but when the pressure is increased, the water is forced into the small hole through which you put the shot and the water rises in the figure, causing it to sink.

A piece of hollowed candle makes a good diver or a medicine dropper in a medicine bottle will work very well. Fill the bottle with water and push in the dropper, which will float. Now put in the cork and press it down. The pressure will be increased, water will enter the dropper, and it will sink. If you now ease the cork a little, so that the pressure is decreased, the dropper will come to the surface, and you can make it rise or fall by pressing the [illegible] the bottle with your fingers. You would not [illegible] glass would bend in and out without breaking, but it does, just sufficiently to alter the pressure inside. Another variation is to fit a cork, through which a glass tube bent twice at right angles passes, to another empty bottle closed with a cork. By pressing the empty bottle you may now make your medicine dropper dive, provided the corks fit well. The air pressure will pass over into the bottle containing water.

The fact that the walls of a glass bottle will bend can be shown in another way. Fill the bottle with water and fit a cork through which passes a very fine tube. Now

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press the bottle with your fingers, and the water will rise in the tube. You should make sure that the bottle is at blood heat for this experiment, otherwise the mere heat of your hand might be sufficient to make the water rise. This experiment is better if you use coloured ink so that you can more easily see the water in the tube.

A Miniature Fountain.—A miniature fountain, in a large fruit jar, is made by pushing the tube in the apparatus described above down to the bottom of the bottle, and filling the bottle only three-quarters full of coloured water. Seal the cork in with wax to make sure that it is perfectly air-tight. Then place the bottle on a greased plate or piece of wet blotting paper and invert over it the fruit jar, which has been previously heated over a flame. The hot air will contract as it cools, drawing the water up the fine tube and making quite a showy fountain.

An Automatic Water Trough.—An automatic water trough for dogs or poultry can be easily made if you remember the barometer principle. Fill a bottle with water and by means of wire fix it inverted in the trough and with its mouth under the water. When the water from the trough is taken by the animals or birds, more water will automatically fall from the bottle, ensuring a continuous clean supply as needed.

The Walnut Diver.—With a little patience a walnut can be turned into a diver. Split a good walnut into halves and remove the kernel and waste. Stick the two halves together again with sealing wax, making the joints air-tight, except for a small hole in one end. Tie two threads to the sealing wax and attach to them a small head or other object. Now place the whole in a jar of water and tie the rubber over the mouth as before. The walnut will sink and rise and can be made to spin round and dance by a series of rapid pushes on the rubber.

Wind Resistance.—One of the most important aspects of the air to-day is the "wind pressure" caused by moving quickly. A car travelling at about ninety or one hundred miles an hour may use as much as one horse-power in overcoming the resistance offered to the air by a projecting headlamp. The whole object of designers of rapidly-moving vehicles of all kinds, cars, locomotives and aeroplanes, is to reduce wind resistance. By holding a candle two feet in front of you, with a sheet of stiff paper just in front, you can see how the vacuum created by a rapidly moving object sucks it back. If you blow, the candle flame is not put out, but it bends over towards the paper and the direction of the draught. The wind streaming past the edges of the paper creates a partial vacuum, and bends the flame back.

The opposite effect can be obtained by blowing through a funnel. A good deal of amusement is caused by a competition in which each person in turn is given a funnel and is told to blow out a lighted candle. However hard they blow down the small tube, the spreading effect of the funnel will disperse the compressed air, and the candle will remain unaffected.

To Blow a Cork into a Bottle.—Here is an experiment in which the reverse happens; the air current is concentrated and is therefore made far more powerful. Lay a bottle on its side upon the table, and in the mouth of it place a piece of cork. The trick is to blow the cork into the bottle. This cannot be accomplished by blowing into the bottle in the ordinary way, but if a straw or clay pipe is used and the air blown directly on to the cork, the latter will go inside.

To Blow Out a Candle Behind a Bottle.—Try this trick of a somewhat similar nature. Place a lighted candle on the table, and about ten inches in front of it a wine bottle. Then blow on the bottle at a distance of eight or nine inches, and the light will be extinguished just as though there were nothing between it and your mouth. The breath divides into two currents on the smooth surface of the bottle, one going right and the other left, and these rejoin just at the flame of the candle.

Always recollect that in dealing with any experiments with gases you are really working with a substance that is similar to a solid or a liquid, but that it takes less time for internal movements to take place. It is time which decides whether a substance is a gas or a solid. Liquids are those materials which conform to the shape of the containing vessel. But a high-speed camera shows that the process takes time, and that a solid will act in like fashion if more time be available. Gases can be poured when heavy, like water. If they are lighter than air, they can still be poured; but the "displacement" is upwards.

WATER

Water, having weight, exerts pressure in exactly the same way as everything else. The force of water coming from a high level to a low level is used all over the world to turn turbines and the dynamos that generate electricity. You can make a small water motor for yourself by fitting a wheel with a number of vanes that hold the water and are forced down by its weight. The mill wheel is really a water motor, being turned by the weight and energy of the water, just as a windmill is turned by virtue of the weight in the air.

A pretty experiment to show the force of water can be performed with one of those old-fashioned glass shades which used to stand on Victorian drawing-room mantelpieces, with a clock or ornament underneath. Carry a jet of water from the tap to a basin and then make a number of small cork balls. When these are placed in the inverted shade, the force of the water will throw them up in the air over and over again. The jet of water is forced up through a hole in the top of the inverted shade and is used in much the same way as in shooting ranges where it is made to support a light ball.

Water in large quantities can exercise enormous pressure, but the pressure depends not entirely upon the amount of water in the vessel. The height of the water in the vessel and the area of the base are the important factors. It is this fact that makes it possible to build a hydraulic press. The upward pressure of water and other liquids can be simply demonstrated. Take a glass tube, an oil-lamp glass will serve, and cut a piece of cardboard to cover the bottom. To the centre of the cardboard attach a piece of string and, holding the cardboard in place with the string, lower the glass into a vessel of water. If the string is relaxed, you will find that the cardboard still remains in place, being held by the upward pressure of the water. Gently pour some water into the tube, and when the level of the water in the tube is the same as that of the water surrounding it, the cardboard will come away.

A Labour-saving Device.—Just as balloons float by displacing a definite weight and amount of the air, so boats float when they displace an equal weight of water. There is a very good story which illustrates how a practical man can save himself trouble and labour by a knowledge of the laws of science. This particular person had to take a horse carrying two tubs down to the river, fill the tubs with water and return with them to a farm. Now to fill the tubs meant either taking them off the horse's back, pouring in the water and then replacing them, a very tedious task, or leading the horse into the water and submerging the tubs while they were still upon the horse's back. This also is a difficult business because of the vessels buoyancy and one which would probably end in the horse being drowned.

So this man cut a hole in the bottom of each tub and fitted a small door on a hinge. When the horse entered the water, the pressure of the water forced open the door and the water rushed in. Then when the tubs were filled, the horse was led out, the pressure of the water in the tubs closed the doors and kept them shut. This is an example of a very simple valve, and you can very easily make a small model for yourself. A can fitted with a valve in the bottom is useful for watering the garden, when the water has to be obtained from a rain-tank.

The Principle of Hydraulics.—One of the earliest scientists to study hydraulics was Archimedes and he evolved a principle which still holds good after thousands of years. This ancient philosopher showed that when a body was immersed in water, it was buoyed up by a pressure equal to the weight of liquid displaced. Now you see why it is easier to swim in the sea than in fresh water. If you fill two large jars, one with a strong solution of salt and the other with pure water, you will find that a fresh egg will sink in the pure water, but float in the salt water. The reason is, obviously, that the weight of salt water displaced, not the volume, is greater than the weight of the fresh water; a fact, that salt water is denser than fresh water, is very easily verified by weighing.

With a little experimenting, you can produce a liquid with a density exactly equal to that of the egg, and in this solution the egg will float in any position. Half fill a jar with salt water and place the egg in it. Now add, little by little, fresh water, stirring it round. The egg will rise or fall according to the density of the liquid. If it rises you should add a little more fresh water; if it sinks, a little more salt water. Eventually there will come a time when the egg will stay anywhere in the liquid; either at the bottom, in the middle, or on the top.

When you press a tumbler or other empty vessel into a basin of water, you can feel the upward pressure of water on the bottom, and the more you press down, the greater becomes the pressure. Actually, this pressure is equal to a column of the water equal in size and height to the amount of tumbler submerged. This was proved by the experiment with the glass tube and the cardboard end because the stopper does not float away until the height of water inside and outside the tube is exactly the same. In other words, the upward pressure of the water is equalled by the pressure of the water in the tube.

The principles of water pressure have to be very carefully studied by the designers of ships. Cut two prisms about two inches long; one out of cork or very light wood, and the other out of a heavy wood like mahogany. Now place them in fresh water. The light prism will float with its edge down and a face up, but the heavy prism will float with its edge up and a flat surface on the water. A popular form of this experiment is to construct a "fish" out of a prism of deal wood and place it first in fresh water and then in salt water. You will find that the fish will float with an edge down in fresh water—looking as if it were dead, but with an edge up and flat surface down in salt water, seeming to have come to life.

Capillary Attraction.—Water and other liquids have many peculiar properties, two of the most interesting being capillary attraction and the "meniscus." The word capillary is derived from the Latin for a hair, and very fine drawn glass tubes are called capillary tubes. You can make your own by drawing out a piece of ordinary glass tubing in a wide flame, taking care to keep the tube moving all the time you are heating it, so that it is evenly heated all round and does not crack.

When a capillary tube is plunged into water, the water rises in the tube and, within limits, the narrower the tube, the higher the water will rise. Why? This effect is due to the attractive force between atoms, for at the bounding surface of a drop of liquid in air, the outer atoms pull inwards and this pull is, naturally, balanced by outward forces. In a small drop of water the internal pressure from these causes amounts to nearly two atmospheres.

When surface tension causes water to adhere to glass, the usual curved "meniscus" is observed in the containing tube and we have a concave "meniscus"; that is to say, the top of the water in the tube, instead of being level, is higher at the sides than in the middle. Mercury, on the other hand, does not adhere so strongly to glass. If you look at a barometer, you will see that the "meniscus" is convex, higher in the centre than at the sides.

It is easy to show that the narrower the space for the water, the greater will be its rise. Take two pieces of plate glass and tie them face to face with a piece of string. Now plunge the bottom into water and the water will rise rapidly between the glasses. If you now insert a knife edge in one side, so that the plates are separated partly on that side, you will find that the water will drop, but will remain at the same height on the other side, where the glasses are still very close together.

The "Meniscus."—An amusing way of demonstrating the "meniscus" and its great power is to fill a glass of water to the brim and then to begin dropping in pennies, very carefully. If you were to ask someone how many pennies you could drop in without spilling any water, they would probably reply "One or two." Actually, the answer is ten or twelve, according to the shape and size of the glass. Drop the pennies in very carefully, and you will see a kind of convex "meniscus" rise higher and higher until it is far above the edge of the glass. The surface tension will prevent it from overflowing until it has risen a considerable distance, but once this tension is broken, the water will flow over rapidly.

Here is a variation of the above experiment. Gently pour some water through a funnel into the glass until it is full to the rim, which must, however, be kept perfectly dry. If the rim becomes wet, the water will run over, so that great care is needed in filling the glass. Drop a few pins at a time in the water, and the glass can be filled with them without the water running over. Avoid splashing the water on the rim of the glass when putting the pins in. The glass will probably hold considerably over 2,000 pins and no water will be spilled.

Drops of water have considerable power of cohesion. If you watch drops running down the window pane when it is raining, you will notice how one drop joins another, and yet another, until the loading becomes too great and the drop breaks up. In the same way, if you dip your finger into water and watch the drops fall off the end, you will see the drop elongate and stretch considerably, before it breaks off and falls.

A "Racer" for Water Drops.—A very amusing experiment is to make a "racer" for water drops. Your course must be made of oiled paper or paper which has been coated with lamp-black. You need a strip two feet long and a few inches wide. Place the paper over a succession of smaller and smaller objects, so that it forms an up and down course, each little hill being smaller than the previous one. Now let a drop of water fall on the crest of the highest hill, and the drop will run down the slope, gathering sufficient momentum to carry it over the next hill and so on, until it gets to the end of the course. It does not break up, because the paper is oiled, if, however, you were to use ordinary paper which "mixes" with water, the drops would not roll, but would spread out over the surface.

The surface tension on a glass of water can be made the basis of an interesting experiment. Bend a long strip of cardboard twice at right angles, so that you can balance it on the edge of a glass. Pour in water until its surface is just touching the bottom of the cardboard. You will now find that you can place a number of coins on the arm hanging outside the glass without disturbing the balance. The arm touching the water, although not under it, is held by the surface tension.

To Make a Needle Float.—Take an ordinary needle, and put it upon a fork, and slowly lower the fork into a tumbler of water; the needle will then float just like a piece of straw. The reason of this is that a "meniscus," or bed, convex on one side and concave on the other, is formed upon the surface of the water; and the surface of this "meniscus" being large in comparison with that of the needle, the latter is supported by it so that scarcely any part of the needle is touching the water; of course, if the water penetrated the needle's eye, the weight of the fluid would cause the article to sink immediately. Another method is to put a leaf of cigarette or tissue paper on the surface of a tumbler of water, lay a needle gently upon the paper, which will soon become soaked and sink to the bottom of the glass, leaving the needle floating on the top of the water.

The Grape Seed in the Glass of Champagne.—Yet another experiment. If a grape seed, quite dry, is placed at the bottom of a glass filled with champagne, owing to capillary attraction, the bubbles will attach themselves to the seed, and it will rise to the surface of the wine, where the bubbles burst and disappear. Then the seed will fall to the bottom of the glass again. The seed in this instance has been raised to the surface by the aid of the air bubbles, which play the part of little balloons in bringing it to the top of the liquid.

Capillary attraction and "meniscus" are due to molecular attraction. A diverting way of examining this phenomenon is to place two corks in a basin of water and watch their behaviour. Sooner or later they will approach each other and if you watch carefully, you will see that just as they are approaching, they suddenly rush together, the molecules have, so to speak, come within striking distance of each other.

We can take it that very much the same sort of thing takes place amongst the molecules of a liquid, although these particles are, of course, much too small to be seen, even with a powerful microscope. If you fix one of the corks on the end of a knife, you will be able to drag the other round with it, just as if you had a magnet and small piece of steel. Now try these experiments after giving the corks a coating of grease. They no longer behave in the same way, because the tension is locally destroyed by the grease. Camphor, by its solubility, not only acts like grease, but sometimes imparts a rapid motion to the float.

The Siphon.—Most people know the siphon and how it works. It is a most useful application of the principles of physics. A very simple siphon can be made by immersing a rubber tube in water until it is full, and then placing one end in a raised glass of water and the other end in an empty glass. The water will rapidly siphon over into the empty glass. If you raise the glass that was at first empty above the level of the other, the water will flow back. Owing to capillary action a siphon can also be made with a piece of cloth. Simply dip one end of the cloth in the full glass and place the other in the empty glass, and the water will pass over. This property of textiles is the reason for the efficacy of the wick of a paraffin lamp, the oil ascending the fibres by capillary action. Without this force, flowers and trees could not exist, for it is the motive power for the circulation of sap.

Tantalus.—The principle of the siphon has been used in the past for many amusing toys and novelties, and some of these might be revived with enjoyment and possibly profit. There is, for instance, a working model of Tantalus, a gentleman, you will remember, who was condemned to stand in water and yet never be able to drink, because whenever he stooped the water ran away.

You can make a figure of Tantalus, cut out of wood or shaped in tin. Inside his body run a glass tube bent in a hoop so that the opening is hidden in the folds of his cloak, about half-way up his body. The other end of

the tube is connected to a concealed pipe connected with the sink. If you now pour water into the containing vessel, it will rise until it reaches his waist, but after that, however much you pour in, it will never reach his mouth. As soon as it reaches his waist, it begins to be siphoned away.

Diffusion. When two different liquids are brought together, but not stirred, they will slowly mix by the power of diffusion. This is particularly easy to notice in the case of coloured liquids. Mix some red ink with water in a wine glass. Fill another wine glass with pure water and have it ready. Over the surface of the glass containing the red ink, place a piece of porous material such as butter-muslin or window curtaining. Bring the edges over the side so that when the glass is inverted no liquid comes out, the upward pressure of the air will keep it in. Then place the glass containing the red ink exactly over the mouth of the glass containing the water. After some time you will notice the red ink penetrating into the water, diffusing is the correct term, and after several hours, the whole would probably become properly mixed. This property is used in the case of gases to detect the presence of explosive mixtures in coal mines. Even solids will flow into each other if the time available is sufficient.

SOAP BUBBLES

In the soap bubble we see the working of both surface tension and capillary attraction. For experiments with soap bubbles you need a better solution than the plain water and soap flakes generally used. The addition of a little glycerine, or even sugar, will give stronger bubbles with a longer life.

A liquid will always take up the smallest position possible under the conditions of its existence. That is why, if you blow a soap bubble in a pipe and then remove your lips the bubble will contract until it is a thin film stretched across the mouth of the pipe. Blow again, and the film will stretch out into a bubble once more.

The power of contraction is considerable, as a simple experiment with a soap film will show. Bend a piece of wire into the shape of a rectangle and make a "bridge" of thin wire, which when it hangs over the edges of the figure, divides the rectangle into two parts. Dip the whole into a solution, and film will form across the rectangle. Push your finger through one side of the film, so that it "explodes," leaving the film still on the other side of the bridge. Now you will see that the film contracts, and as it does so, exercises sufficient force to drag the "bridge" along with it. If, instead of a wire bridge you use a piece of cotton, you will find that you can draw the film out into a convex shape. A "skeleton" cube made of wire and dipped into a soap solution will have films formed on all its surfaces, and the effects when it is removed are very beautiful to watch. The thin films "separate" the component colours of white light and, if thrown upon a screen, the changing colours as the films shrink are particularly interesting.

A soap bubble, of course, contains compressed air which stretches out the film. This air can be used to blow out a candle. Make a film over the mouth of a funnel and blow the bubble as large as possible. Then put your finger over the end, and hold the "nozzle" towards a lighted candle. When you remove your finger, the contracting bubble will expel the air with sufficient force to blow out the candle. This is quite as effective as the vortex rings produced by tapping the back of a large box which has a hole in the cover.

With wire rings, produced simply by making a hoop of wire and twisting the ends together to form a handle, you can make some extraordinary soap bubbles. Take two of the rings and place one at the top and one at the bottom of a soap bubble. If you have previously wetted the rings, they will not break the bubble, but will cling to it so that it is supported between them. Now draw the rings slowly apart, and the bubble will become cylindrical or barrel-shaped. While a friend holds this curiously-shaped bubble, dip a piece of glass tubing in the soap solution and very gently push it through the skin of the bubble, so that its mouth is in the middle. Then blow very gently, and a second bubble will be formed inside the first. With care and patience this may be detached and the tube withdrawn. If you blow only a small bubble in the inside, and turn the rings round so that the barrel is horizontal, the second bubble may be made to roll inside the first.

With a certain amount of practice three bubbles can be made one inside the other, but for this you should use a funnel rather than a pipe for blowing; or better still, a cork with a hole in it, as in this case the bubble will have a big base on which to rest.

On a saucer that has been raised from the table, place a cork on top of which is half-a-crown. On top of this again, place a smaller cork on which is a shilling. Wet all the apparatus well before starting. Now blow a large bubble with your funnel and let it rest on the saucer. It will not break and with care you can detach the funnel. Then wet a piece of glass tubing well, and push it through the bubble. Blow another smaller bubble on the half-crown and, with a light tap on the tube, detach it. Finally, push the tube through both the bubbles and blow one on the shilling, again detaching it with a tap. You may fail once or twice, but with practice you will find that you can obtain the three bubbles, and if your soap solution is good, they will last for some time.

A flat spiral of very fine wire can be made to revolve on the top of water by surface tension. The wire must be dipped in oil to make it float and should then be placed in the middle of a basin of water. Fill a dropper with alcohol or brandy and drop the liquid a little at a time in the centre of the wire. The spiral will turn forward. The alcohol has less surface tension than the water, and the resulting pull from outside makes the wire revolve.

Bubbles blown by gas from the main can be ignited in the air and, with suitable chemicals, they can be caused to ignite spontaneously, but the risk of fire is rather serious. Many of the most wonderful effects to be seen in a soap bubble under conditions of stress are so rapid that they can only be shown by the use of a high-speed camera. Some bubbles are so strong that when a bullet is fired through them, the bubble bends inwards where the bullet strikes it, and the column of air inside pushes out the opposite side of the globe until it swells and bursts.

EXPERIMENTS IN CHEMISTRY

CHAPTER VI

EXPERIMENTS IN CHEMISTRY

EVERYONE knows what a porous material is and that it can absorb other substances such as air and water. This can be made the basis of an amusing experiment, and if you so desire, a deceptive illusion. Drop a moth-ball into a glass of soda-water. The ball will immediately sink. In a very short time, however, it will rise to the surface, and will then presently sink again. The alternate rising and sinking will continue almost indefinitely.

For the purposes of deception you do not, of course, say that you are using soda-water, but leave it to be assumed that you are using tap water. You state that you wish to demonstrate the power of mind over matter and that without in any way touching the ball, you will make it rise and sink at will. Time your commands " Rise " and " Sink " to coincide with the natural movements of the ball and it will appear that it is obeying you. The explanation is, of course, that the moth-ball " breathes " air. It sinks at first because it is heavier than water, but in a short time it takes up some of the gas, becomes lighter and rises to the surface, where it gives off the gas, and then sinks, to repeat the process over again.

Sugar that Floats.—Colloids are amongst the most interesting substances known to chemists ; they are the basis of many everyday things such as artificial silk and celluloid films. An amusing experiment is possible if you purchase a little collodion solution from the chemist and dip some lumps of sugar in it once or twice. Allow the lumps of sugar to dry for at least twenty-four hours and then drop them in the sugar bowl, where they will be indistinguishable from the rest.

Now when your friend puts this specially-treated sugar into his tea, he will be surprised to see it bob up again in a few minutes, and however many times he pushes it down, it will refuse to sink. When you have had a laugh, explain that the sugar was "doctored," and advise him to throw away the cup and have another with genuine sugar. The explanation is that part of the sugar dissolves, leaving behind the insoluble and light collodion framework as a kind of airtight bag. This retains the shape of the sugar and is strong, but does not bear very close examination!

Turning "Milk" into "Water."—All sorts of changes in colour in solutions can be brought about by adding various substances. This fact has been taken advantage of in the past by conjurers who have claimed to change milk into water, water into ink, and ink into wine. Fortunately for their health, they have always ignored the advice of the more sceptical members of their audience to "Drink it," or our hospitals might be full of conjurers!

Some of these changes are interesting and startling. The "milk" used by conjurers is often a mixture of concentrated solutions of sodium carbonate, or washing soda, and calcium chloride, another cheap and common chemical. If you place this milky-looking liquid in a tumbler and pour in hydrochloric acid, it is instantly cleared and looks like pure water. You will have to experiment with the exact quantities required, because if you do not use sufficient acid, your solution will remain cloudy. The explanation of this experiment is, of course, that the calcium carbonate or "chalk" produced when the two solutions are mixed is insoluble in a neutral mixture, but soluble in an acid solution.

There is another method of turning milk into water,

but I do not recommend it, because the chemicals are not easy to keep. You require silver nitrate, which is used in making photographic materials, absolutely pure sodium chloride—common salt, which is impure sodium chloride, will not do—and ammonia. Nitrate of silver and sodium chloride produce a milky liquid which clears instantly when ammonia is added. A word of warning—when pouring in the ammonia, see that the glass containing the "milk" is still. If you move it about, a precipitate resembling curdled milk will be produced. The slight "fizzing" is due to the release of carbon dioxide gas.

Chemists use a number of substances which they call "indicators" because they change colour when placed in an acid or alkali. Litmus is the most commonly used. A little of the liquid, or a piece of litmus paper placed in even a very dilute solution of an acid, such as acetic acid or vinegar, will turn red. Placed in a solution of an alkali, such as carbonate of soda, or caustic soda, it will turn blue. If you wet your finger with your tongue and then place a litmus paper on it, you will see the litmus turn blue, showing that your saliva is alkaline. Other indicators also show it to be an alkali.

Turning "Wine" into "Water."—Another good indicator is a substance called phenolphthalein, and this is the best for the "turning wine into water" experiment. Phenolphthalein solution is colourless in contact with an acid, but turns red in contact with an alkali.

Prepare three solutions. In the first put a teaspoonful of phenolphthalein in a pint of water. In the next make a strong solution of washing soda, and finally, a strong acid solution. Acetic acid will do, but tartaric acid, used in baking, is better. All three of these solutions are colourless. Now, if you pour a little of the phenolphthalein solution into the carbonate of soda solution, the whole liquid will turn a bright wine colour. Pour this "wine" into the other glass of "water," which is the acid, and it will turn colourless again. As phenolphthalein is only slightly soluble in water it can be dissolved in a little "spirits of wine" and then added to the pint of water if a stronger solution is required.

The Magic Glasses of Water.—Try this experiment, in which the results are somewhat similar to those in the foregoing one. Have four tumblers prepared in the following manner:—Place a small portion of fine ground and sifted red sanders (sandalwood) in the first glass, rinse the second with a little vinegar, place a small quantity of potash in the third, and a little alum in the fourth. Water poured into the first glass will assume the colour of claret, pour this liquid into the second and it will immediately change to a brandy tint, on turning it into the third glass it will resume its previous colour, i.e. claret, and when this is poured into the fourth glass it will become black.

The Magic Jug of Water.—Here is another effective trick. Fill a glass jug with the liquid in which some red cabbage leaves have been boiled for half an hour. It will be purple in colour, and when cold is ready for use. Take three tumblers, leave the first quite clean, in the second place a drop of ammonia, and in the third a drop of sulphuric acid.

Pour some of the cabbage liquor into the glasses, and that in the clean glass will retain its colour, that in the second glass will turn green and the third, red. This is a very effective and amazing trick, as all the liquid is poured from the same bottle or jug, into clear glasses.

A very effective colour change is that made in a copper sulphate solution by ammonia. Make the solution so dilute that its blueness is barely apparent. Then drop in a little ammonia and the mixture will instantly become intensely blue throughout.

"Invisible Inks."—"Invisible Inks" which only appear in colour when "developed" are easily made in a large variety of colours. One of the simplest is that made with

cobalt chloride. Dissolve a few crystals in water and then write with the solution with a clean pen on ordinary paper. The writing will be invisible until you warm the paper, when it will appear in blue. The writing will fade as the paper cools and the chemical absorbs moisture, but may be brought up again with heat.

Potassium ferrocyanide will give a brown invisible ink. It can be developed either by heating or by dipping the paper in milk. Ordinary ink consists of a mixture, except fountain pen ink, which is usually an aniline dye, of an iron salt and pyrogallic acid. If you write with iron sulphate, the letters will be invisible when dry. But if you develop by brushing the paper with pyrogallic acid, the two chemicals will mix and the writing will show up in black. A somewhat similar method has been used for cleaning old documents or for examining the "faking" of manuscript by various forms of artificial light.

Another invisible ink that can be developed with heat is potassium nitrate dissolved in pure acetic acid or vinegar; when heated this shows up pink and disappears again on cooling. One of the most interesting invisible inks is made from bismuth nitrate. If you write on a piece of paper with this material, the writing will be invisible as long as the paper is dry, but appears as soon as it is wetted.

Writing made with a solution of silver nitrate can be developed by exposing it to daylight, but the solution must be very dilute or the paper will be injured. The writing appears in brown and if no sunlight is visible, exposure to the fire will bring about the same result.

If you have no chemicals available, you can make invisible ink with lemon or onion juice. The writing is quite invisible until exposed to warmth. Suppose you suspect that a blank piece of paper has invisible writing on it; how can you develop it? You can, of course, try all the standard developers, such as heat, wetness, sunlight and ammonia. If these fail, you must resort to another mechanical method. The chances are that when the writer traced his pen over the paper, he disturbed the surface. The roughing is so minute that it is probably invisible, even under a magnifying glass, but if you obtain some powdered graphite by sharpening your pencil " lead " and blow this on to the paper when it is dry, the powder will stick where the paper has been broken, and can be blown off in the untouched places, thus revealing the writing. Aluminium powder will serve the same purpose. This is the method used by detectives for " developing " suspected finger prints. Press your finger on the outside of a tumbler, for instance. Nothing will be visible, but if you blow on powdered graphite or aluminium powder, the finger print will stand out boldly. When you gripped the tumbler, the minute quantity of grease which is always present on your skin, left an impression of the ridges, and although this was invisible to the naked eye, it became apparent when the light powder stuck to the glass. Aluminium powder can burn very quickly ; it is the basis of some welding materials, so treat it carefully as you would celluloid.

" Magic " Drawings.—Before leaving the subject of invisible inks, here is a method of making " magic " drawings. Using copper sulphate for the trunk and branches and chlorides of cobalt and nickel for the leaves, draw a tree. Now warm up your picture, which will be invisible when dry, and you will see the trunk and leaves appear in their correct colours. An alternative method is to draw the trunk and branches in pencil and the leaves with green invisible ink. The tree may then be made to " grow " by warming it. There are endless variations of this device, many of Japanese origin. For instance, you may draw a bluebell, using ordinary pencil for the stalk, cobalt chloride for the leaves and copper sulphate for the flowers. Only the stalk will be visible, but if you first warm the paper and then hold it over a jar of ammonia, the leaves will appear in green and the flowers in deep blue. The blue will fade away when you remove the ammonia fumes.

You may have seen at some time or other a sheet of glass which appeared to be perfectly plain, but which, when breathed upon, showed a picture. This illusion requires the use of hydrofluoric acid, a chemical which is not very expensive, but which must be handled with the greatest care. It is kept in a rubber bottle and you should wear rubber gloves when handling it, being very careful that it does not come in contact with your skin. Use a new quill pen and on the glass draw the picture you require with the acid as ink. After five or ten minutes, wash all the acid away under the tap and dry the glass. Now you will find that if you breathe on it, the picture will appear. The acid attacks the glass, etching on the lines of the picture. Chinese magic mirrors are similar in principle.

Acid bottles have their names sandblasted or etched on with hydrofluoric acid in this way ; or the whole glass surface may be coated with varnish, which is scratched away where required, and the bottle dipped in the acid, which acts where the glass is exposed. The easiest way for the home worker is to coat the plate in paraffin wax, scratch on the name and then hold the glass above the acid, the fumes will be sufficient to attack it.

The " Blushing Lady."—This is very simply made when you know the working of sensitive indicators. Sketch the portrait of a lady and daub her cheeks and neck with a solution made by mixing equal quantities of methylated spirits and water and adding a little phenolphthalein. Allow the portrait to dry, and the lady will look quite normal. But damp her a little and hold her over an ammonia bottle so that the fumes reach her and she will blush violently.

There are some very pretty colour changes to be obtained with " time reactions." The solutions are complicated, but the exact moment of a change can be calculated and the "command" given by the performer at the right moment.

Experiments in Spontaneous Combustion.—Combustion, as you know, means burning, and some substances have such a violent affection for each other that they combine instantly with the evolution of light and heat. This is called "spontaneous combustion." Crush a little chlorate of potash and mix it carefully with a little loaf sugar which has also been crushed. Place the mixture on a plate, dip the end of a glass tube in sulphuric acid, and let a drop fall on to the mixture. There will immediately be a burst of flame owing to the violence of the chemical action.

If the powder and the acid are placed on opposite sides of the saucer and covered with a sheet of paper, a good trick can be performed by pretending to light the paper by breathing upon it. As you breathe, tilt the saucer and the acid runs into the sugar mixture at the right moment.

Break up some copper nitrate crystals, add a little water and roll them up quickly in a piece of tinfoil, such as is used for wrapping cigarettes. Place the ball on a plate and in a minute or two, smoke will start to rise. Then the whole will catch fire. If the desired result does not take place rapidly, sprinkle a little more water on the tinfoil.

Charcoal can be made to take fire by pouring over it nitric acid. In case any hot fragments are thrown out, the charcoal should be put in a small cup placed in the middle of a soup-plate of water. Pour on the nitric acid and there will be many lively sparks.

A Safe Explosive.—A perfectly safe explosive can be made if the directions which follow are carefully followed. Do not be tempted to increase the quantities given. Take three or four crystals of iodine and powder them very carefully. Then place them in the bottom of a clean test tube and pour over them a very little, not more than a teaspoonful, of strong ammonia. Allow the mixture to

stand for half an hour and then carefully filter it through a paper. A brown substance will be left behind and on no account must this be allowed to dry before it is divided into a number of minute portions, each the size of a pin's head. These should be placed on separate pieces of paper and allowed to dry in a safe place. If you touch the powder with a hammer or disturb it with the end of a long, hot needle, it will explode with a loud report. This fulminate is perfectly safe as long as only very minute quantities are used. It can be painted on to door handles and will often explode when touched. Not more than a mere speck must be used, for it may detonate by the touch of a fly walking across its surface.

Flash Paper.—Flash paper which burns with an intense light can be made simply, but here again caution is necessary in carrying out the details of the preparation. Carefully measure four parts of sulphuric acid and five parts of nitric acid, stirring well with a glass rod. Then take some sheets of paper, it must be unglazed, and dip it in the solution for ten minutes. Remove the paper with a glass rod, taking great care never to let your hands touch the acid, and place it in a shallow plate of water. Wash the paper by changing the water every hour or so, or by letting it hang under a running tap. Then dry the paper carefully and cut it into strips before it is quite dry. When lighted the paper will burn with a flash, leaving practically no ash. The flame may be coloured by soaking the sheets for a few seconds after they have been finished in a solution of copper chloride, potassium nitrate, strontium chloride or barium chloride, which will give blue, violet, red and green respectively. By adding a small fulminating cap, these papers can be made to flash when rubbed between the fingers.

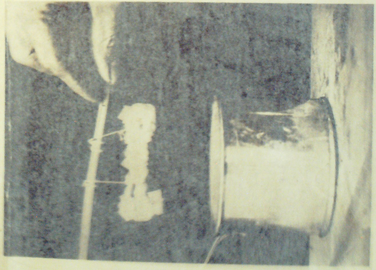
Fire Extinguishers.—Water is commonly looked upon as the best fire extinguisher. It forms a blanket over the flames, preventing any oxygen from getting to them, and, as you know, there cannot be any ordinary combustion or burning without oxygen. Other liquids and gases which are not inflammable make a good blanket for extinguishing fires. Carbon dioxide is sometimes used and in the case of oil fires many kinds of extinguishers have been tried. Water is nearly useless, as being heavier than oil, it sinks, while the oil on the surface continues to burn. The ideal is a non-inflammable liquid which is very light, but unfortunately nearly all light liquids are inflammable.

The action of carbon dioxide as a fire extinguisher can be shown quite dramatically. If you prepare carbonic acid gas by pouring hydrochloric acid on to marble and allow the warm gas to rise into a tube which is bent down to touch the base of a wide basin in which half-a-dozen candles are alight, the candles will go out. Another way of demonstrating this action is to fill a jar with carbon dioxide and invert it over a row of candles. The candles will go out one after the other. Carbonic acid gas is heavier than air and so can be poured downwards. If you balance two jars of air with their mouths upwards on a pair of scales and then pour into one of them a jar of carbonic acid gas, the scale will fall, the heavier gas displacing the air.

Lighting a Cigarette with Ice.—Although water is usually associated with putting out flames, it can be used to start a fire. Ice will do and the experiment may be made very dramatic. A neat way of demonstrating this apparent contradiction is to take a small piece of potassium, about three times the size of the head of a pin, insert it in th end of a cigarette and then touch it with a piece of ice The cigarette will immediately catch fire.

The explanation is that potassium reacts with water freeing hydrogen gas. The action is so vigorous that sufficient heat is generated to light the escaping hydrogen. A warning is necessary before you try this experiment. Potassium is dangerous and should always be kept under oil or naphtha, as the moisture in the air may be sufficient

This anchor is formed of alum crystals that have attached themselves to a piece of copper wire bent into the required shape. (See page 198.)



Shapes of copper wire may be immersed in a saturated alum solution that crystallizes on them.

to start it burning. Nor should you ever touch it with your hands, for there is always a little perspiration on the skin and you would be burned. The metal should always be handled with a pair of tweezers and cut under oil. If you are putting the potassium in a cigarette, use a cork tipped cigarette so that there can be no possible mistake about which end you put in your mouth. Even then, a holder is best, so that there is no possibility of what would prove a serious accident.

Tricks with Hydrogen.—If you throw a very small piece of potassium or its kindred metal, sodium, on to water, it will react so vigorously that it melts and rolls about on the surface. In the case of potassium, the hydrogen will burn with a purple flame, the colour being due to the vapour of the metal. If you try this experiment, be careful to use only a small piece of the metal, certainly not larger than a pea. A similar principle is used in the automatic floats used for life-saving at night. Calcium phosphide is the chemical in this case and gives off inflammable gas at such a temperature that ignition takes place.

You can collect the hydrogen given off by putting a piece of potassium or sodium in a small lead tube or container, which will take it to the bottom of a bowl of water. Over the rising stream of bubbles you should place another container filled with water, with its mouth under water. The gas will displace the water, and in this way you can fill a number of jars, preventing the gas from escaping by pushing a greased plate over the mouth or by turning them upside down.

Many interesting experiments can be performed with the hydrogen collected in this way. If you hang an empty jar mouth downwards from the arm of a pair of scales and balance it with weights, you can then pour hydrogen upwards into the jar, and the weights will fall, showing that the balance has been destroyed. Hydrogen is much lighter than air and hence its use in airships.

Here is a very amusing deception you can try on your friends—passing smoke from a cigarette smoked in one corner of the room into a closed jar in another corner. To prepare for this experiment, place a few drops of ammonium hydrate—usually called "ammonia"—in the bottom of a tumbler, and on the bottom of a saucer or plate put a few drops of strong hydrochloric acid. Now, having announced that you will pass the smoke from your cigarette into the tumbler, close the tumbler with the prepared saucer or plate, blow a few puffs of smoke, and presently it will appear in the tumbler. What has really happened, of course, is that the hydrochloric acid and ammonia have combined to form the dense white fumes of ammonium chloride which look not unlike cigarette smoke. If anyone removes the plate and smells the fumes, they soon know that they have been deceived!

"Pharaoh's Serpents."—One of the most popular chemical amusements is "Pharaoh's Serpents." These are made of mercuric thiocyanate, a substance which gives a voluminous ash when it burns. The best plan is to buy a little of the thiocyanate, your chemist may know it better as sulpho-cyanate of mercury, and make up cones by stirring it into a thick paste with water and gum. When you light one of these cones, the ash will curl slowly out like a serpent, but as the fumes are poisonous, the experiment should be performed in the fender so that the noxious gas rises up the chimney.

The great disadvantage of this substance is undoubtedly the poisonous fumes given off, and although if handled with care it is safe, another serpent can be made which is non-poisonous. This is prepared by powdering together two parts of bichromate of potash, one part of nitrate of potash and one part of sugar. Mix them thoroughly, after you have powdered them separately, and make small paper cones into which you press the mixture. Light the cone

at the top, and the ash will squirm out, but not quite so voluminously as the orthodox Pharaoh's Serpents.

Tricks with Phosphorus.—The phenomenon of phosphorescence can be made the basis of a number of interesting experiments, but in dealing with phosphorus, you should always keep it under water and cut it under water. If exposed to the air, the heat caused by the friction of the knife may be sufficient to set the phosphorus on fire. To prepare "liquid" phosphorus, heat one part of phosphorus in six parts of oil of almonds, very gently, for two hours. The mixture should be in a flask and placed in a sand bath. The oil will become charged with phosphorus and must be kept in the dark and well stoppered or it will lose its peculiar properties.

I should like to repeat the warning that phosphorus is a material which must be handled with the greatest care. It should be cut under water and must never be touched except with tweezers, when it can be cut with a knife without difficulty. Use only a very small portion at a time and never expose it to air for more than a few moments before the experiments

"Ghosts."—Any substance painted with this oil will glow in the dark, emitting a weird light. "Ghosts" of a very frightening kind can be made by daubing a face mask with the liquid phosphorus. The nose, mouth and eyes, being gaps in the mask, appear as black cavities, while the rest of the face glows with an unearthly light. It is essential to use a mask for this experiment, in order to prevent the oil from touching the skin. Phosphorus itself must never be handled, for the burns which might occur are usually very serious and poisonous in character. Writing which can be read in the dark can be prepared by holding a small piece of phosphorus in a pair of tweezers and writing. The words will glow in the dark.

Lighting a Candle with a Glass of Water.—Another good experiment with phosphorus is to light a candle with a glass of water. The glass is prepared by sticking a very small piece of phosphorus to its side with a little candle grease. Now light a candle and pinch it out with your fingers. If you tip the candle towards the glass of water, just touching the phosphorus with the wick, it will light again. Of course, it is not really the water which lights the candle, although it appears to be so. It is the phosphorus that is set on fire by the hot wick.

One final warning about phosphorus. Never use it in pieces larger than a pea and never touch it with your fingers. The substance is quite safe if properly handled, but these two rules, and that about keeping it under water, should be carefully observed or you may easily get a septic burn.

Will-o'-the-Wisp Gas.—A very interesting gas is phosphoretted hydrogen, which is made by the decomposition of vegetable matter in the bottom of ponds. The gas takes fire spontaneously in air and gives a peculiar smoke which goes up in rings. This gas is responsible for the "will-o'-the-wisps" seen in marshy districts. It is most easily prepared by dropping a few lumps of phosphide of calcium into water, when decomposition takes place immediately, the gas lighting in rings as soon as it comes into contact with the air. This gas, sometimes known as phosphine, has a most unpleasant smell, like that of rotting fish. It is poisonous and so must not be breathed.

Combustion Under Water.—In preparing mixtures of powders, always remember to powder each ingredient separately. If you grind them together, you may generate heat and, if they are combustible or explosive, you will possibly have an accident. This is particularly necessary in the following experiment. Powder one part of potassium nitrate and three parts each of gunpowder and sulphur. Mix them well together and pack them into a cylinder made of strong paper—an empty sporting cartridge is best. Drop the cylinder mouth downwards into a tall jar of

water, and brilliant combustion will take place under water.

Fire-resisting Solutions.—Substances soaked in alum often become incombustible. You can, for instance, soak an old handkerchief or a piece of paper in alum solution for some time, then dry it and attempt to set it on fire. It may smoulder sullenly where you apply the match, but it will not take fire. Nowadays asbestos cloth is used when there is any danger from fire, as this is absolutely fire resistant.

An amusing experiment is to soak some strong string in a concentrated solution of common salt, dry it thoroughly and then soak it once more. The oftener this is done the better. The string looks quite ordinary, but it has an extraordinary property. Hang a curtain ring from it and then set fire to it. The string will burn up, but the ash will continue to support the ring! The explanation is, of course, that the string has taken up so much salt that after the fibre has burned there is sufficient salt left to prevent it breaking. In performing this trick take care that there is no draught near. Cigarettes from which the ash will not fall have been made by mixing a very little asbestos wool with the tobacco.

A more elaborate form of this experiment is to prepare a small handkerchief or square of muslin by tying a thread to each corner and soaking it as before. You can then place quite a heavy object in the middle, hang the handkerchief up by the threads and set fire to it. The cloth will not break; if you use an egg as the object, the experiment is even more interesting to the audience!

A "burning" form of secret writing requires a solution of potassium nitrate as the ink. Write in large bold letters, connecting up the words. When it has dried, hold it over the flame of a match. The writing will take fire in one spot and the spark will travel right round, cutting out the letters, but leaving the rest of the paper intact. The opposite of this may be obtained by writing with asbestos paint, when, after drying, the paper will all burn away except where it is coated with asbestos.

Experiments in Crystallization.—Some very interesting experiments in crystallization may easily be performed. Gigantic crystals of alum can be grown as follows. Make a strong solution of alum and hang in it a long hair or even a piece of thin thread. In twenty-four hours or so, you will probably find a small crystal adhering to the hair or thread. Now dip this crystal on the end of the thread into a solution of alum, made by boiling the crystals with water until no more will dissolve. The crystal will grow very rapidly and in the course of a day or two you may obtain a large crystal, an inch or more across.

Supersaturated solutions, electrically assisted, afford some extraordinary results. They help to show the crystalline nature of many metals and the manner in which all matter appears to live.

Large crystals of many salts can be made in the same way, but if you wish to grow really effective examples, you must keep giving your crystal fresh solution to feed upon. Sugar crystallized in this way is a popular sweet under the name of "sugar candy."

An amusing variation of this type of experiment is to cover an ornament with crystals. Make your ornament out of wire, it may be a few simple turns, a skeleton basket or a bunch of wire flowers. Suspend the wire in a solution and after a short time, the whole will be covered with a mass of small crystals. Copper sulphate, giving blue crystals, is a good salt to use for this purpose, but you can add any stain you like: litmus will give you red; indigo, blue, and so on.

A Chemical Garden.—A chemical garden is most interesting to make and, if you set about it carefully, you will get some beautiful growths in charming colours. You will want a fish globe or some other glass vessel in which to make the chemical garden. Into the bottom of the vessel put a layer of sand about two inches in depth. Now on the sand put a few lumps of sulphate of copper (to be secured from a chemist), some odd scraps of aluminium, which can generally be obtained from a motor garage, and a few odd bits of iron, like nails. Mix these things well up on the sand. Now from a chemist get some waterglass (sodium silicate) in syrup form such as is used for preserving eggs. Make a mixture by adding three times as much water as you have waterglass, stirring well together. You should have sufficient of the mixture nearly to fill the globe. Pour on the mixture steadily, taking care not to disturb the chemicals which you have arranged in the sand. Stand the whole thing on one side for a few days and something surprising happens. There appears a dense growth of the silicates of the various substances, which takes on strange forms in all kinds of pretty colours. The chemical garden will look better if you now get rid of the waterglass solution and have plain water in its place. You may upset the delicate growths if you try to tip out the liquid, so the best way is to stand the globe in the sink and then let a small stream of water pass into it until all the waterglass has passed away, leaving nothing but clear liquid through which all the curious growths can be plainly seen.

Making Metal Trees.—Lead trees are a very effective ornament. Dissolve two ounces of lead acetate in about a pint and a half of distilled, or rain, water. Shake the mixture and allow it to stand for at least two days. Then filter your solution and return it to the jar. From the cover suspend small pieces of zinc. Leave the jar absolutely undisturbed for a few hours and when you return, you will find a beautiful "tree" of metallic lead. The branches are often very realistic when illuminated. Tin and silver trees can be made in much the same way. For a tin tree use nitrate of tin in smaller quantities and add a few drops of nitric acid to the water. Suspend a piece of zinc as before. For silver, you need a little silver nitrate dissolved in pure water and set aside for a short time. Then add metallic mercury equal to half the weight of the silver nitrate and the silver tree will be formed. Camphor will also give a tree if it is dissolved in "spirits of wine" and then poured on to a sheet of clean, cold glass.

Miscellaneous Chemical Experiments.—Gilding steel is not a difficult experiment, although gold salts are not cheap. Mix together a little sulphuric ether and nitrate of gold, and into the mixture dip a pocket-knife or other steel object. It will be gilded and the gold will stick better if you polish and burnish the steel. By painting with the mixture, you can write your name in gold on any steel object.

An amusing experiment is to throw an empty egg shell into a jar of dilute hydrochloric acid. The egg will sink, but after a few minutes it will rise again and spin round slowly. The hydrochloric acid acts on the chalk in the egg shell, giving off carbonic acid gas. It is the evolution of gas that makes the shell rise and turn round.

A Bottle Cannon.—When certain chemicals are mixed together in water, you get effervescence or, in other words, a liberation of gas. A familiar instance is the Seidlitz powder. The powder is enclosed in two separate packets. In the blue paper there is soda and potash, while in the white there is tartaric acid. Now if the contents of the blue paper are dissolved in water and then the contents of the white paper stirred in, you get a tremendous bubbling, which is due to the liberation of carbonic acid gas. The amount of gas produced is considerable, as you can show by making a bottle cannon. Get a good-sized bottle and let this be about a quarter full of water. Dissolve the contents of the blue paper in this. Make up a little roll of paper, and into this put the contents of the white packet. The roll is tied at both ends and attached by a piece of

wire to the cork of the bottle. Allow this packet to drop down into the bottle and then push in the cork. Now let the bottle rest on one side and soon the soda and potash solution will soak through the paper packet. Then generation of gas starts and this is soon sufficient to send out the cork with a loud pop.

To Smoke with Two Empty Pipes.—Procure two pipes, preferably of clay. Dip a piece of paper in spirits of salts and smear it over the inside of the bowl of one of the pipes; treat the other pipe in the same way with liquid ammonia.

Hand one of the pipes to a member of the company, and ask him to smoke it. Of course he cannot do so. Then hand him the other empty pipe, ask him to place the two bowls together, and he will be able to blow out clouds of smoke.

A striking experiment can be performed by dusting a number of feathers with aniline powders of different colours. If you blow off the surplus powder, they will seem to be still white, but if you spray the feathers with eau de cologne or scent, the different colours will come up vividly. If you have a suitable piece of glass and an arc lamp, you can also view the feathers under ultra-violet light and can cause certain colours apparently to disappear.

Everyone who has been camping knows that a rope contracts when wetted. This fact can be utilized in lifting a heavy weight. Attach a long rope to the object, and then tie it to a beam in the ceiling so that it is just taut. Wet the rope and the object will be lifted off the floor. There is an amusing story of a Cavalier Fontana, who had undertaken to raise an obelisk to Pope Sextus V in Rome, He had all but given up the difficult task, when he h an inspiration. "Wet the ropes," he shouted, and column rose of its own accord on to the pedestal had been prepared.

Should you at any time have access to a chemical laboratory, there are a number of wonderful effects which can be produced by the action of light upon certain chemicals. One fascinating experiment showing this phenomenon is demonstrated by mixing chlorine and hydrogen in a thin glass flask. As soon as a bright light is shone upon the vessel, the gases explode as if by magic. Most of the really wonderful things of this kind which can be so easily carried into practice are based upon principles that are perfectly simple when understood.

An experiment which you might well call the " Mystery of the Bloodstained Hand " can be performed quite simply. Thoroughly moisten some muslin with a solution of sodium salicilate and, when dry, place it over a piece of board. Now make a solution of ferric ammonium sulphate, which will look more or less like water. You have only to dip your hand into the " pure water " and press it against the muslin sheet, when a red mark will appear almost immediately.

SOME OPTICAL ILLUSIONS

CHAPTER VII

SOME OPTICAL ILLUSIONS

THERE is an old saying that seeing is believing, but this is not by any means always true. The fact of the matter is that, because you think you see a thing, it does not by any means always follow that it is as you think. Wonderful as the human eye undoubtedly is in its construction, it has its faults and limitations, and these cause it at times to deceive us over the most simple matters.

Look at this arrangement of twelve black squares separated by white bands (Fig. 58) and keep your eyes fixed on them. After a few moments you will notice a curious illusion, small shadowy black dots appearing in the centres of all the crosses formed by the white lines. Of course, these shadowy black dots are not there at all really, and immediately you concentrate your gaze on any one of them, it disappears. It is only your eyes that have taken you in.

Then turn to the next figure (59) and look once

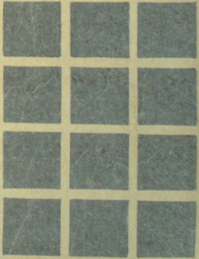


FIG. 58. SHADOWS THAT PLAY HIDE-AND-SEEK.

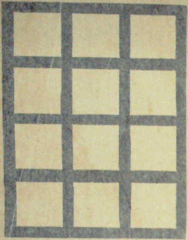


FIG. 59. THE ELUSIVE WHITE SPOTS.

more at the twelve white squares with their black margins. This time you will see shadowy white spots appearing in the centres of the crosses formed by the black margins. Look hard at any one of these mysterious shadowy dots and it immediately disappears while others seem to spring up in the spaces around. Shift your gaze to another and it likewise disappears while the one you had previously been concentrating on immediately reappears.

As I have previously mentioned, a bright object usually gives a much stronger impression on the retina than a black one. Hence, if you look at the two accompanying squares (Fig. 60), you will doubtless think that the white one on the black ground is the larger. In fact, they are exactly the same size, as may be quickly verified by actual measurement. Owing to certain imperfections of the human eye, the image of a luminous point on the retina is never quite sharp. The images of the luminous points on the edges of the white square invade the black border, and in the same way the white border appears to invade the black square and make it look smaller. In the same way, if you look at an electric lamp when it is alight, you will be able to see the filament quite easily. It looks quite a thick piece of wire, but examine it when it is cool and you will find that in reality the wire is most finely drawn. The difference is not due to expansion of the wire, which is too small to be observed, but simply to the fact that the bright object makes a stronger impression. Actually, the wire does not change in size at all. It only appears to do so.

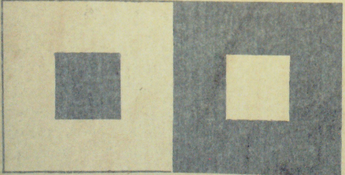


FIG. 60. WHICH IS THE LARGER OF THE INNER SQUARES?

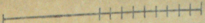


FIG. 61. A DIVIDED LINE LOOKS LONGER THAN ONE THAT IS NOT.

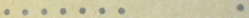


FIG. 62. ANOTHER EXAMPLE OF FIG. 61.

The eye is always eager to make comparisons, and for this reason a divided line always looks longer than one which is not divided. This is clearly illustrated in Figs. 61 and 62. The direct perception of the several parts makes us notice the number of the subdivisions, the size of which is more perceptible than when the parts are not marked off.

The judging of distance also is not so easy as one might think. Here is a simple little test for you. Which is the

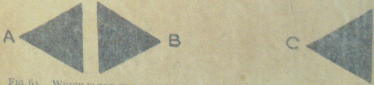


FIG. 63. WHICH IS THE GREATER DISTANCE? From A to B, or from B to C?

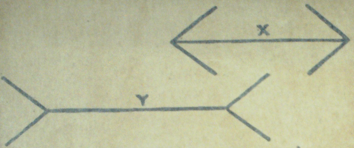


FIG. 64. WHICH IS THE LONGER LINE, X OR Y ?

greater distance, from A to B in the figure (63) or from B to C ? You will doubtless have no hesitation in saying that it is farther from B to C than from A to B. But you will be wrong, for both distances are exactly the same. Measure them for yourself and see.

Now glance at Fig. 64. Which is the longer line, X or Y ? Of course you will say Y immediately, but here again you will be wrong, as this is merely a variation of the earlier figure, and the horizontal lines are exactly the same length.

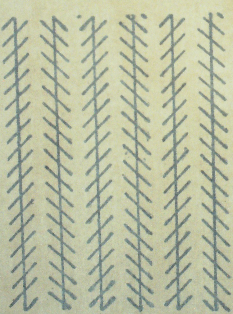
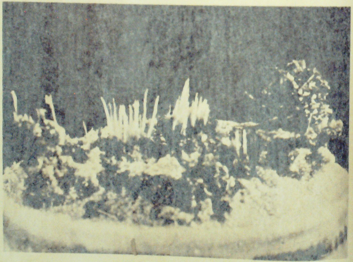


FIG. 65. ARE THESE VERTICAL LINES PARALLEL ?

MAKING A CHEMICAL GARDEN.—I.

Iron, sulphate of copper and aluminium are placed in a glass bowl and covered with a water-glass solution.



A CHEMICAL GARDEN.—II.

Growths of the silicates of iron, sulphate of copper and aluminium in water-glass solution. (See page 198.)

This illusion is purely due to the introduction of the arrowheads which in one case point inwards and in the other outwards.

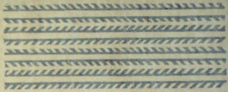


Fig. 66. The four horizontal rules are perfectly straight and of even width.

The mistakes of the eye have to be taken into account by architects and builders. Evidently, the ancient Romans had studied these illusions, for on the fresco paintings of Pompeii are lines which should be parallel and are not parallel when measured mathematically, but are bent so as to compensate for the effect of adjacent lines. "Perspective," which every artist learns early in his career, is another illusion. It means that parallel lines going towards the horizon appear to meet and have to be drawn so that, if produced, they would meet at a distant point. This is necessary because, as you will remember, the eye judges distances by comparing one eye's view with the other, and the farther away a spot is from the eye, the nearer together are the lines of vision from the two eyes.

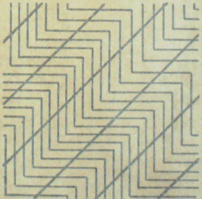


Fig. 67. Another example of Fig. 65. The diagonal lines are quite straight.

Oblique lines always have a disturbing effect on our sense of direction. In Fig. 65, for example, the vertical lines are really quite straight and parallel, although they appear to slant alternately in different directions. The illusion in this case may be increased considerably by means of turning the diagram sideways at an angle of about forty-five degrees. Another instance of this form of illusion is clearly illustrated in Fig. 66, where the four horizontal rules are perfectly straight and of even width, although, at a first glance, they do not appear to be so. Their straightness may be tested by means of laying a ruler along them.

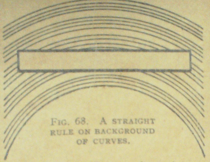


FIG. 68. A STRAIGHT RULE ON BACKGROUND OF CURVES.

Yet another example of the effect of oblique lines is shown in Fig. 67, where the diagonal lines are all perfectly straight and parallel in spite of their irregular appearance. Test them with the ruler and see.

In Fig. 68 is shown the strange effect produced by placing a straight rule on a background of curved lines. The rule appears to bend upwards at the ends in the opposite direction to that followed by the curved lines. Actually, of course, the rule is quite straight. A variation of this illusion may be obtained by drawing an equilateral triangle on a background of circles. The sides of the triangle, although perfectly straight, will appear to bend inwards in the centres.

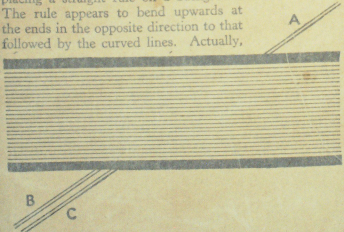


FIG. 69. WHICH IS THE STRAIGHT ROD, AB OR AC?

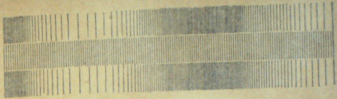


FIG. 70. EFFECT PRODUCED BY PARALLEL LINES.

Now look carefully at Fig. 69. Which is the straight rod, A B or A C? You will doubtless have no hesitation in saying A C. But here again your eyes will have deceived you. A B is the straight rod, not A C, as may easily be verified with your ruler. This is another illusion due to "irradiation."

In Fig. 70 is shown the curious effect produced by a series of closely and widely spaced parallel lines, or shading, upon a centre band made up of evenly spaced parallel lines as shown in the diagram. The closely spaced lines, or dark shading clearly tends to lighten up the centre strip and make the parallel lines appear wider apart, whereas the widely spaced lines have the opposite effect.

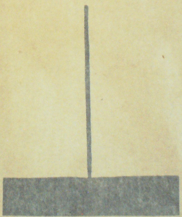


FIG. 71. WHICH IS THE LONGER, THE THIN VERTICAL LINE OR THE THICK HORIZONTAL BAR?

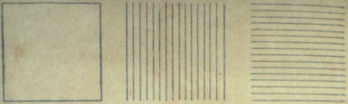


FIG. 72. WHICH OF THESE SQUARES IS THE LARGER?

The eye is very bad at comparing perpendicular and horizontal lines. If you draw on a piece of paper a thick horizontal line and then extend from the middle of it a perpendicular line of exactly the same length (Fig. 71), you will find that your first impression is that the horizontal line is much shorter than the other.

Now look at the three squares illustrated (Fig. 72). In spite of the fact that they are all exactly the same size, they look entirely different, and strange to say, although we have just shown that a perpendicular line looks longer than a horizontal line, the square composed of horizontal lines here looks bigger than the square composed of the same number of perpendicular lines.

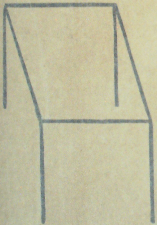


FIG. 73. ARE YOU LOOKING AT THE TOP OR THE UNDERSIDE OF THE TABLE?

NAWAB SALAR JUNG BAHADUR

Here are two more very curious little optical illusions. In the first (Fig. 73) you see what looks like a table with four legs. When you look at this first of all, it seems as if you were looking at the top of the table. But if you keep on looking at it, things seem to change, and you will presently think you are looking at the underside of the table. Of course, nothing really happens and it is only your eyes that are playing you tricks. Now look hard at the arrangement of rings (Fig. 74) which appears to be like a pipe. First of all the pipe seems to be lying on its side, but if you keep on staring at it, the whole thing suddenly appears to change completely, so that now the pipe seems to be standing on its end. This is, of course, merely another illusion as no actual change takes place.

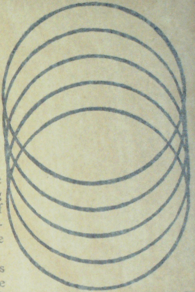


FIG. 74. IS THIS TUBE ON ITS SIDE OR STANDING UP?

There are other things which appear to change places, even while we look at them, although they do not really alter their positions at all. Our eyes are merely playing tricks with us. Look at Fig. 75 and say how many cubes you see. If you see seven, look at Fig. 76 and then back at Fig. 75 and count the cubes again. There are now only six, apparently, but a glance at Fig. 77 and back at Fig. 75

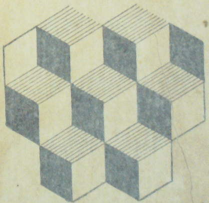


FIG. 75. HOW MANY CUBES ARE THERE HERE?

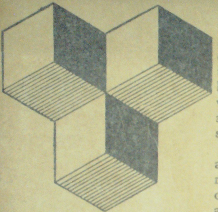


FIG. 76. COMPARE THIS WITH FIG. 75.

again quickly restores the missing cube. And now as you look at the cubes in the first figure, they seem to change backwards and forwards of their own accord, first there are six and then seven.

Another form of this apparent rapid change may be seen in the case of Figs. 78 and 79. Look at Fig. 78 and you will have no hesitation in saying that the black wall is nearest you, and that the staircase mounts upwards. But if you look steadily at the lower figure (Fig. 79) for a moment or two and then back at the top one, you will instantly change your mind. It is now clear that the white wall is nearer to you and the staircase is inverted. And it appears to change from one to the other while you gaze at it.

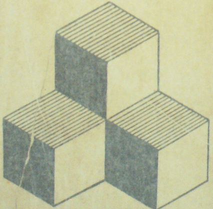


FIG. 77. AND NOW COMPARE THIS WITH FIG. 75.

A very amusing illusion is that of the Bee and the Flower (Fig. 80). Hold the figure straight in front of you on a level with the eyes and about an inch and a half from your nose. Look intently for a moment or so, and slowly the bee appears to fly over and settle on the flower.

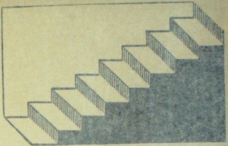


FIG. 78. WHICH IS NEAREST, THE BLACK WALL OR THE WHITE?

Here is an optical illusion with a ring. Suspend a ring by a string, on a level with the eyes, with the plane of the ring towards the person. Tie a small stick crosswise on the end of another about a yard long; hold the long stick, shut one eye, and try to thread the ring with the crossed stick. Success is not likely to be attained, but if both eyes are used, the ring can be threaded at the first attempt.

This trick may be varied by using only a crooked stick instead of two sticks tied crosswise.

The following is an illusion that will cause great surprise. Put a shilling into an ordinary tumbler half full of water; place a plate on the top, and turn the glass over quickly, so that the water does not escape. On the plate a coin the size of half-a-crown will appear, and a little higher up another the size of a shilling. It will add to the effect of the experiment if one of the company who does not know the trick is requested to throw the water away, and save the pieces. He will be surprised at only finding one.

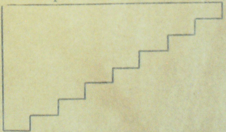


FIG. 79. NOW LOOK AT THIS AND BACK AGAIN AT FIG. 78.

Here is an interesting experiment that demonstrates the fact that light is only made evident, as far as the eye is concerned, when it is scattered or changed in direction. Prepare a disc of glass of similar size to a penny. Have this disc concealed in a pocket, then place a handkerchief over a penny and hold it over a glass full of water. By putting the hand to the pocket, ostensibly for a pencil with which the penny is tapped to show that it is still under the handkerchief, the glass disc can be substituted.

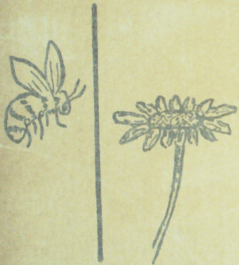


Fig. 80. The bee and the flower.

If this imitation penny is then dropped into the tumbler and the handkerchief removed, the sound is heard but the glass remains invisible and the penny can be said to have dissolved. When the water is poured out, surface attraction prevents the glass disc from falling away.

Our next figures (81 & 82) illustrate the well-known optical illusion of wheels that spin round and round. If you hold the design (Fig. 82) in your hand and give it a twirl by means of a slight circular movement of the wrist, you will apparently set the wheels of the bicycle turning round and round. The faster you move the design, the faster the bicycle seems to travel. A reversing movement will make the wheels appear to spin in the opposite direction. The effect is more satisfactory if we do not look too directly at the wheels. These rotating wheel movements are particularly striking in combinations such as that represented in Fig. 81, in which a multiplicity of circles does not allow us to fix our gaze definitely on any one wheel.

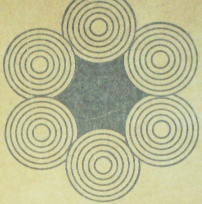


Fig. 81. A combination of wheels.

Fig. 83 represents three people walking down a passage. The figure farthest away appears the largest and the man nearest seems to be the smallest. This, however, is an illusion. The figures are all exactly the same size, as may be tested with a ruler. Here the laws of perspective mislead us; we cannot successfully estimate the size of the figures apart from the setting.

How Tall is a Hat?—This suggests an illusion with

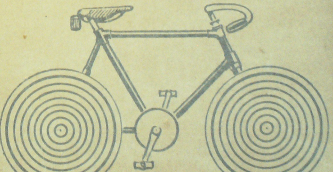


Fig. 82. The bicycle.

which you will catch the vast majority of people. Pin a large sheet of white paper against the wall, touching the floor at the bottom. Then, when no one is looking, place a black object—a top hat serves very well—on the floor immediately in front of the paper (Fig. 84). Notice the height to which it comes on the paper and remove it before anyone else sees it. Then ask those present to come forward one by one and mark on the paper the height to which they think the hat would come. Finally, make your own mark and place the hat in position. You will find that your friends will all be a long way out, and, unless you are very careful, you will be wrong yourself! Most of the marks will be far too high.

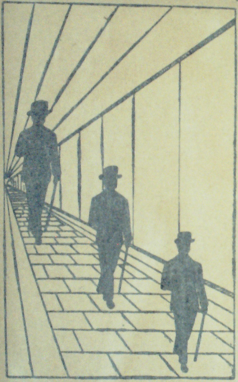


FIG. 83. WHICH OF THESE FIGURES IS THE TALLEST?

Here is an optical illusion with a watch. Borrow a silver watch, and cover the back with the tips of the first, second and third fingers of both hands. Hold the back of the watch towards the audience, gently move the watch to and fro, at the same time part and rejoin the finger tips a little. The watch will look as if it were bending.

A little trick on the eyes, which is really a most curious puzzle, is carried out in this way. Cut a piece of card which is four and a half inches long and one and three-eighths inches wide. On this draw out the figures to indicate eleven match-sticks, as shown in Fig. 85. Now draw a diagonal line across the card, one end of which just clears the top of the first match-stick and the other the bottom of the last. Cut along the line with scissors so that the card is in two pieces. Put the two halves on the table in their original position and count the match-sticks to make sure that there are eleven. Now move the upper half of the card one stage along in the manner shown. Count the match-sticks, and to your amazement there are now only ten. Move the upper half back again to its first position, and you will have back again the original eleven match-sticks. Few people will guess the explanation of this puzzle, which can be explained as follows. The eleventh match is really there all the time, but not as a whole. When you have cut and moved the card one stage to the left, this has the effect of dividing one of the matches into ten parts. Each of the ten matches in the

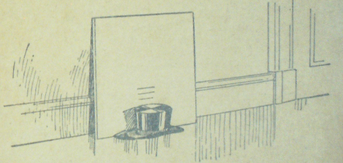


FIG. 84. HOW TALL IS A HAT?

arrangement is just a tenth of a match longer than it was before, but the difference is too small for your eyes to detect.

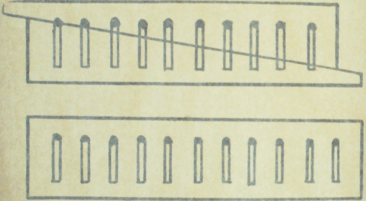


FIG. 85. WHERE DOES THE ELEVENTH MATCH GO?

Our eyes take every opportunity of giving themselves a rest, and this results in a number of illusions. For instance, if you look very hard at a black object for a minute or two and then look away at a dark background, you will have the impression of a black object reversed in white. For example, in Fig. 86 you see a funny little figure like a black sprite. Look hard at this while you count twenty very slowly. Then transfer your gaze to a rather dark wall-paper or book cover and you will be surprised to see a ghostly figure in white move across the surface. Next fix your gaze on Fig. 87 for a few moments and then look at a dark wall-paper or surface, and the black skeleton will appear reversed in white on the dark background. What happens is that the constant vision of the black or white tires the part of the retina on which it falls; so when you look at the background, the tired part refuses to be stimulated, with the result that the image appears in the reverse of what you actually saw it. We also must always remember that black is not a colour, but simply the absence of all light.

It is interesting to note that optical illusions fail to deceive the eye when they are seen for the barest fraction of a second. If you arrange the illusions so that you can see them by the light of one electric spark, you will find that the squares no longer appear to be of different sizes and the parallel lines do not appear to meet. The spark gives plenty of time for the form of the illusions, but not sufficient time for the eye to move and be deceived.

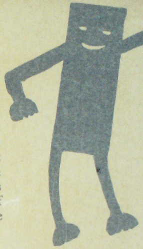


FIG. 86 THE SPRITE.

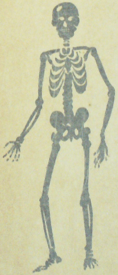
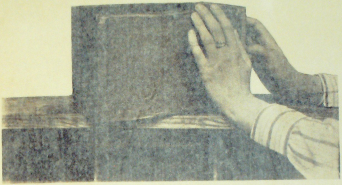
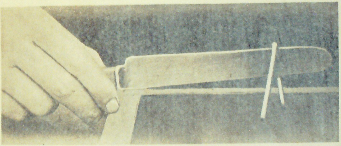


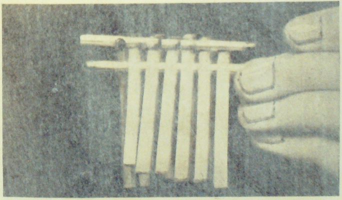
FIG. 87.
THE SKELETON.

With a simple toy that anyone can make you get an X-ray effect. From a piece of thin card cut a strip about six inches long and one inch wide. Half an inch from each end of the strip cut out a round hole half an inch in diameter and fold the strip of card in the centre so that these holes fall exactly one above the other. It is easier to fold the strip of card first and then remove the two round pieces of card together. Between the holes slip a white hen's feather, fix with gum and trim away flush with the top and bottom of your card strip. Now stand in front of a window and place your hand about fifteen inches from your X-ray toy, the opening of which is kept close to your nose. Move your hand backwards and forwards to get the focus, and you will soon find a position where the shadows of the bones of your hand can be distinctly seen.

TRICKS WITH MATCHES AND NUMERALS







1. A box for making smoke rings. (See page 247.) 2. The walking match. (See page 227.) 3. To lift twelve matches with one. (See page 226.)

CHAPTER VIII

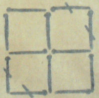
TRICKS WITH MATCHES AND NUMERALS

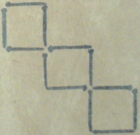
CONSIDERABLE entertainment can be obtained from the following very simple tricks, for which practically the only accessory needed is a box of ordinary wooden matches. Simplicity is the keynote of these tricks, but they are none the less puzzling and amusing.

Four Squares Changed to Three.—Lay twelve matches to form four equal squares as in the first illustration, and then remove and replace four matches so as to make only three squares of the same size as the others. It is accomplished in the manner depicted in the second diagram.

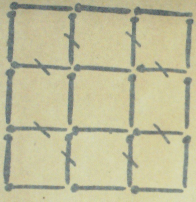
To Form Four Triangles with Six Matches.—Lay three matches upon the table and form a triangle with them. Then make a pyramid with the other three by resting the heads together and inserting the base ends in the corners of the triangle.

Lay Twenty-four Matches on a Table to Form Nine Squares. Take Away Eight Matches and Leave Two





Squares Only.—Make the nine squares in the following manner :—



Now take away the eight matches marked with a cross ; two squares only remain, one in the centre of the other.

To Multiply a Number of Matches.—This is accomplished by laying the matches to form Roman numerals, e.g. three matches will make four or six, i.e. IV, VI ; two matches will make five, V ; nine matches will make three dozen, XXXVI. Another method is to make letters with the matches, and to spell the number, e.g. eleven matches will make nine, NINE.

To make nine matches into three and a half dozen, make two heaps, one containing three, and the other, six matches, i.e. three and a half dozen.

To Lift Twelve Matches with One.—Lay an ordinary household match on the table, and, across it place twelve others. The trick is to pick them all up in one action without spilling. Lay another match across the twelve in the same direction as and exactly over the one underneath. Then raise the bottom match slowly, and the matches can be lifted.

The Walking Match.—Bend a match in half, i.e. making a prong, and on the top of the prong paste or fix a vignetted picture of a man. Place the inside of the prong upon the edge of the blade of a knife, and hold the latter parallel with the table, so that both ends of the match just touch it. The match will then "walk" from one end of the knife to the other, without any effort of your own. This can also be done with two matches joined at the ends by splitting one and sharpening the other. They may also be bent in the centre to impart a knee-like appearance.

The Animated Match.—Break the heads off a few matches, and lay the wooden sticks like the spokes of a wheel on the surface of some water in a saucer, with a space about an inch in diameter in the centre. The water must be quite still. Roll a slip of blotting paper about three inches by twelve inches loosely into a tube about as large round as a sixpence, and then let the end just touch the surface of the water in the centre of the saucer ; a minute current is raised, and the pieces of match are drawn towards the blotting paper. To make the matches move away from the centre, instead of the blotting paper use a small piece of soap cut to the shape of a tube or cylinder. When it touches the water, the matches immediately scatter in all directions.

The Square of Nine.—Take twenty-four matches and form a square of eight piles, each containing three matches, so that each side of the square contains nine. Add one, then three, and afterwards four matches in such a way that in each case there are still only nine matches in each side and at top and bottom.

It is accomplished in the following manner :—

Fig. 1.

III III III
III III
III III III

Take a match from the top left-hand corner, and add it to the three in the centre of the top row, now add an extra match to the three in the centre of the left-hand row.

FIG. 2.

II	IIII	III
IIII		III
III	III	III

Now take one match from the top right-hand corner and add it to the pile in the centre of the top row, take one from the left-hand bottom corner, and add it to the pile just above it, and one from the right-hand bottom corner to the pile above that also. Add three extra matches to make each centre pile consist of five, and each corner two.

FIG. 3.

II	IIIII	II
IIIII		IIIII
II	IIIII	II

Take one match from each corner and add it to each of the centre piles. Then add an extra match to each of the centre piles.

FIG. 4.

I	IIIIIII	I
IIIIIII		IIIIIII
I	IIIIIII	I

The sides of the square contain nine in each case.

An Optical Illusion with Matches.—Here is an interesting optical illusion that may be performed with three matches. Arrange three matches in the form of a capital Y on a black background, placing them so that there is a slight gap between the arms of the Y and the upright, that is to say, although the matches are in the form of a capital Y, none of them is touching each other.

Now gaze intently at the letter you have formed and very soon you will notice a ghostly Y appear at the side of the other one, just a fraction to the right of it.

The Magical Properties of the Number Nine.—If the figures resulting from the multiplication of nine by each figure from two to twenty are added together, the number nine results in each case :—

e.g. $2 \times 9 = 18$, i.e. $1+8=9$. $3 \times 9 = 27$, i.e. $2+7=9$.
$20 \times 9 = 180$; $1+8+0=9$.

Take any given number and reverse the order of the figures, then subtract the smaller number from the greater. The difference is always divisible by nine without a remainder, e.g. :—

678425
524876
9)153549
17061

If a much bigger number, running into millions is taken, the result is still the same, e.g. :—

684,107,233
332,701,486
9) 351,405,747
39,045,083

When only three figures are used, the result is the same, and the quotient will always read backwards and forwards the same, e.g. :—

```
  864
  468
  ———
9)396
  ———
   44
```

MISCELLANEOUS EXPERIMENTS AND TRICKS

CHAPTER IX

MISCELLANEOUS EXPERIMENTS AND TRICKS

IT is said that, in the fourth dimension, you could knot a cord while its ends are held by another person. This may be true, but unfortunately it is not possible to show the fourth dimension "in action." You can, however, invite your friends to take the ends of a piece of cord in their hands and tie a knot in it without letting go these ends. They will probably fail, but the feat can be accomplished.

Place the cord straight out on the table and then fold your arms. Now, with your arms still folded, bend forward until you can take the ends in your hands. Sit back and uncross your hands, you will find that a knot has been tied. If you are "conjuring," you can make this trick very effective by "patter" about the fourth dimension, so that your audience do not see exactly what you do or realize that the crossing of the arms is not accident, but essential.

The Principle of the Pulley.—If you have ever watched men lifting a very heavy object by means of a pulley, you will have noticed that they seem to do a great deal of pulling on the chain in order to raise the object a very little distance. The pulley acts almost like an engine gear enabling them to lift very slowly an object, which in the ordinary way they would not be able to move.

You can use this principle for a very striking drawing-room trick. Challenge four of the strongest people in the room to a tug-of-war. They will probably smile when you suggest that you alone will be able to overcome their united force. The only condition that you lay down is that you shall arrange the rope. This you do as follows. Pair your opponents and give each pair a broom, telling them to hold it heart-high, and making them stand opposite each other, so that the two brooms are parallel and about two feet apart. Now wind your rope round and round the two broomsticks, making about half-a-dozen turns, and take the long end in your own hands.

Tell your opponents that they have to try and pull the broomsticks apart, while you will attempt to pull them together. At the word "Go," pull on your rope, and to the surprise of the contestants, including yourself, you will find that quite a moderate pull on the rope will be sufficient to overcome the straining of your opponents and bring them together.

The explanation is quite simple. If the strands of rope are wound six times round the broomsticks, the force with which you pull will be multiplied by twelve in its action. You will see that, if the broomsticks are two feet apart and you pull them together a foot, twelve feet of rope will pass through your hands!

Perpetual Motion.—Perpetual motion has eluded inventors for hundreds of years and will probably continue to do so, for the element of friction must be present to a degree in every machine. Thus it must one day stop, unless fresh power is added, when it ceases to be true perpetual motion. There is one machine that has been going day in and day out for a dozen years, but this, too must one day stop. It has been going so long simply because the friction has been reduced to the smallest possible proportion, but it cannot be regarded as "perpetual."

You can, however, give a very good imitation of a perpetual motion machine with the aid of a Seidlitz powder, and your machine will be at least as useful as many of those upon which small fortunes have been spent.

Bore a small hole in the lid of a small tin and through the hole place a piece of stiff wire. On either end of the wire fit a small cardboard or wooden disc, so that the wire can move up and down between the discs. Into the tin place a small bottle containing the powder and fitted with a cork in which there is a small hole. Bore a small hole in the bottom of the tin, put on the lid and seal it.

Now place the whole box in a large jar of water. The water will trickle in through the bottom of the tin and the tin will sink until the water reaches the level of the bottle cork, when it will enter through the hole, and gas will be given off. This gas will drive out the water from the tin, for the wooden valve in the top will float in the water and keep the hole in the top shut. The box will ascend to the surface, but as soon as the valve touches the surface, the disc will be depressed and the gas will be able to escape from the top, so that the water will enter from below again and make the tin sink. This process of alternate rising and sinking will continue until the powder is exhausted.

A Sphygmograph.—You have, of course, felt your pulse in your wrist, counting the number of beats made by your heart every minute. Nowadays doctors like to have a graphical record of the pulse beats, and you can make a small instrument for "writing" the beats of your pulse quite easily. It is called a sphygmograph.

Smoke a small piece of glass, this will act as your "paper." Push the "dead" end of a match into the loop of a boot button. Cut a piece of quill or springy wire and push one end into the hook of the button as well. In order to hold your apparatus together, you will require a cork, inserting the button by a slit in the top, and the quill or wire and the match by slits on either side. Bend the wire or quill under the cork, and hold it in position with a pin so that it forms a spring. Now to the "live" end of the match fix a long slim piece of quill or very fine wire so that it forms a quivering horizontal lever.

Stand the apparatus on the table so that the long lever end just touches the smoked glass, and then lay your wrist on the cork so that the pulse is exactly over the button. As the pulse presses and relaxes on the button, the lever will vastly exaggerate the movement, tracing a curve on the smoked glass. If you ask an assistant to draw the glass along at a constant rate, you will produce a wavy line, representing the pulse beats. Do not be disturbed if some of the waves seem bigger than others. It is not because you have heart disease, but simply that your assistant is not pulling the glass at a constant speed. In actual practice, of course, the instrument used by doctors to record heart beats is vastly more delicate in construction.

A Water Mill.—" Mills " which worked by water used to be very popular fifty years ago, although they are rarely seen to-day. One of the easiest to construct is out of four pieces of camphor. Through a small cork pass two needles at right angles to each other so that they form a cross of which the cork is the centre. On the ends of the needles stick small pieces of cork, rectangular in shape and so placed as to face downwards on the water. Now take four small pieces of camphor and with a drop of wax attach them to the pieces of cork, making sure that they all face in the same direction so that, if you go round the parallel edges of the corks, you have first a blank, then camphor, then a blank, then camphor again and so on. If you place this little instrument in a bowl of water, it will spin rapidly round.

The operation is due to surface tension. The camphor dissolves in the water, reducing the tension, so that the other side pulls, and the camphor mill spins round. Even little pieces of camphor dropped in water become very lively because of the " uneven " surface tensions set up.

Another popular mill was the Barker mill, which could be worked in several ways. Here is the method of constructing a very simple mill. Bend the ends of two hairpins so that they are at right angles to the length of the pin. Then with a drop of sealing wax fix the hoop ends of the pins firmly together. Place a pencil with its point upwards on a plate and on this point balance the pins under the sealing wax. If you now pour water very gently on the point of balance, the pins will revolve. Capillary action enables the water to run down the hairpins and round the turns without falling off, and its momentum causes the water to be shot off the ends with sufficient force to turn the whole moving part of the apparatus.

Tricks with Your Wireless Set.—Now a few tricks you can play with your wireless set. If you have a spare loudspeaker or earpiece, you can convert it into a microphone and connect it up with the gramophone " pick-up " terminals of your set. If you conceal this " mike " in another room, you can " broadcast " to your audience. Wait until the news bulletin is being broadcast, and then when the announcer has begun, chip in and give your own news bulletin, which need not be too serious! If your set has no " pick-up " terminals, the microphone should be connected between the grid and filament of the detector valve or the first L.F. valve. It is interesting to ask your audience the cause of noises made, out of sight, and near the microphone.

With a specially prepared piece of apparatus you can give a very good imitation of a " séance." This apparatus takes the form of a loudspeaker mounted on a high stand with a St. George's Cross for feet. In the feet are two nails, with the points just projecting underneath, and from these nails concealed wires run up the stand to the loudspeaker. Before giving your demonstration, you can lift up the stand and speaker, thrusting a stick underneath to show that there are no electrical wires or connection. Then you place the stand in position and to the mystification of your audience, music or speech issues from it. Needless to say, the experiment is much more impressive in a half-darkened room!

What your audience do not know, of course, is that under the carpet are two tin plates connected to wires leading to your wireless set. When you place the speaker stand in position, the nail points penetrate the carpet sufficiently to make a connection. This principle is, of course, the basis of many stage and séance tricks!

TRICKS WITH COINS

The Disappearing Penny.—Gum the rim of a small tumbler, and spread a piece of white paper across it. Then cut away the edges, so that the top of the tumbler resembles a drum. The tumbler is then laid rim downwards upon a sheet of white paper. A penny is laid upon the paper, and the performer places a paper cylinder (which is exhibited to show that it is empty) over the glass, and the two are lifted and placed (still top downwards) over the penny. The cylinder is then removed, and of course the penny, being hidden by the paper drum of the glass, appears to have vanished.

Care should be taken always to place the cover over the glass, when passing it over or away from the coin, also to keep the glass on the sheet of white paper, otherwise the pasted end will be exposed.

To Balance Three Coins.—Lay three pennies with thick edges edge to edge in a row in the left hand, and upon them place a thin strip of wood, slightly longer than the three pennies placed on end. This should have been concealed in the palm of the right hand. Grip the ends of the stick between the thumb and second finger of the right hand, at the same time holding the top and bottom coins tightly. The coins can then be raised perpendicularly, and shown as if self-supported upon their own edges.

To Revolve a Coin Between Two Pins.—Place a half-crown flat on the table, then seize it between two pins held at the extremities of the same diameter. The coin may then be raised without trouble. Blow against the upper surface, and the coin will revolve with tremendous speed, and appear like a metallic sphere.

TRICKS WITH HANDKERCHIEFS

The Dancing Handkerchief.—A long piece of thread is fastened about four feet from the ground at one side of the room, and laid across it. An assistant is placed at the other side ready to receive the thread when desired. Two knots are then tied in a borrowed handkerchief, one at one end, and one in the centre. When the second knot is tied, carelessly drop the handkerchief, and on recovering it pick up the thread also, and tie a third knot at the other end, but round the thread. Now throw the handkerchief on the floor, and taking a stick, wave it over the handkerchief, asking it to rise, which it will do on the assistant gently pulling the thread until the handkerchief is in a perpendicular position. He can then jerk the thread, and the handkerchief will appear to dance.

This trick is most effective if a magnet is used instead of a stick, and the performer says that the handkerchief is magnetized. The thread can be held by two persons, and raised or lowered as desired, the magnet being held some distance above the handkerchief. If the assistants are clever, it will not be apparent that they are holding the thread.

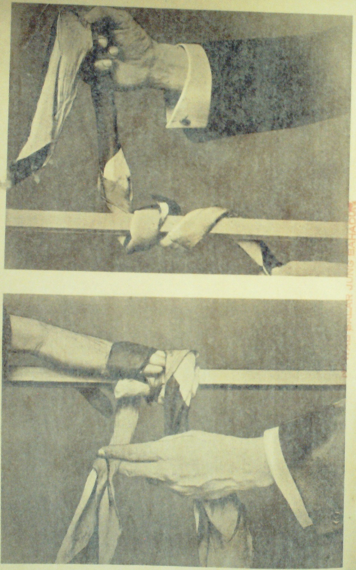
To Balance a Handkerchief.—Push a piece of stout wire, about twenty inches in length and with a very small hook or point on one end, up the left sleeve, leaving the hook towards the hand. Take a handkerchief by the corners diagonally, twist it in the form of a rope, then attempt to balance it on a finger of the left hand. In this you will be unsuccessful, and the handkerchief will collapse.

Now take a corner of the handkerchief in the right hand, and hook it to the wire protruding from your sleeve; drag this through your left hand so that the wire is hidden by the handkerchief. Directly the whole of the wire has been pulled out of the sleeve, again twist the handkerchief ropewise—with the wire inside. You can then quite easily balance the handkerchief on your finger. The hooked end, of course, must be at the top, to prevent the handkerchief from slipping down.

The Mysterious Knot.—Ask two persons to hold a stick between them, twist a long handkerchief ropewise, and wind it twice round the stick, leaving the ends hanging over the stick; let one of the persons lay a hand on the fold, carry the ends of the handkerchief backwards, and wind again, this time round both stick and hand, but carrying the handkerchief the reverse way of the other wind. Tie the ends of the handkerchief together, let the assistant show that he can hold the stick unsupported, and then have his hand drawn away. Pull the knot sharply, and the handkerchief will come away from the stick. Care must be taken not to cross the handkerchief.

To Break a Knot.—Let anyone tie two silk handkerchiefs, rolled ropewise, together and while pretending that you have a very difficult knot to cope with, and that you doubt if you can manage to undo it, pull the knot about, until one handkerchief runs through the knot in practically a straight line. Mask what has been done as far as possible, and then show that the knot has not been untied, but do not let it be examined. Hold it in one hand, and cover with another handkerchief, or else with one hand behind the back.

The other part of the knot can then be easily pushed off the straight piece with two fingers only.



THE MYSTERIOUS KNOT. (See page 240.)

NAWAB SALAR JUNG BAHADUR

To Cut an Apple in a Handkerchief Without Injuring the Latter.—An apple is placed in the centre of a handkerchief, the four corners of which are joined together, tied, and the bag then suspended by a cord from a rod or a hook. Take a sabre or a strong knife with a thick blade, but a very sharp edge—the thicker and sharper the blade, the more likely is the experiment to succeed. A clean upward cut must be made underneath the apple, without sawing, and perpendicularly to the point of suspension. The apple will jump up slightly, and the handkerchief will enter with the blade and be uncut.

A Rope Pulled from Behind Tied Wrists.—Have the wrists tied together with a handkerchief, not too tightly, and a long piece of stout cord placed between the arms and round (i.e. over and under) the handkerchief. Get an assistant to hold both ends of the cord, and immediately he has secured them, thrust the hands forward, bend the fingers of the right hand down, pull the cord up between the handkerchief, pass the back of the hand underneath the loop, and tell the person who is holding the cord to pull it hard. The rope goes off the back of the hand, underneath the handkerchief, which it does not displace.

NAWAB SALAR JUNG BAHADUR

SOME MORE GOOD TRICKS

A good "catch" is to lay a halfpenny on a piece of paper, draw its outline, and cut it out. Now lay a penny over the aperture and challenge anyone to pass the penny through the hole made by the halfpenny. Probably the majority of those present will declare that it is impossible, but you, knowing something of curved space, will promptly crumple the paper, so that it is bent about the hole, when the penny can be gently coaxed through from underneath. You set your audience the problem in two dimensions, length and breadth, and solve it in three dimensions; length, breadth and height.

Another simple, and perhaps better-known, trick is to break a match in the middle so that it does not quite come in two, and placing the angle over the mouth of a bottle, to lay a sixpence on top. The problem is to drop the sixpence into the bottle without touching it. The solution is easy. Just let a drop of water fall from your finger on to the bend in the match. The wood will expand with the water, the angle will open, and the sixpence will drop into the bottle.

In engineering it is often necessary to transform one kind of motion into another. For instance, a wheel going round and round may be required to make a saw go backwards and forwards, or a piston going up and down may be required to make a wheel go round. It is possible to convert movement in any direction into movement in almost any other direction. Here is a simple experiment, based on this principle, which you can perform.

Take a large sheet of cardboard and with a pair of compasses draw a large circle. Cut this out with a sharp knife or pair of scissors, making the cut as clean as possible. Now out of the circle you have removed cut a considerably smaller circle and in the edge stick a pin. If you place the smaller circle inside the larger while it is lying on the

table and wheel it round, what kind of a line does the pin trace through the air? You will find that it traces a straight line, and this can be turned to effect by sticking to the top of the pin the figure of a tight-rope walker. Stretch a piece of cotton straight across the large circle and the height of the pin from the table. Then place your tight-rope walker in position and begin to wheel the circle round and round. You will find that the figure remains on the cotton, showing, of course, that the pin is traversing a straight line.

Candles which go out at the critical moment of a thrilling story are easily prepared, and I do not doubt that they are frequently used by practical jokers. Cut a candle cleanly in two, then take out about half an inch of wick, warm the two ends and stick them together again. When some unfortunate and unsuspecting person takes the candle to bed, it will suddenly go out without warning, the time depending on the exact position in which you divided the candle.

The following trick shows how you can make a candle that cannot be blown out. Roll a linen rag which has been well soaked in salt, or preferably covered with it, round a candle; light the candle, and it will burn, even if placed in the open in a strong wind.

Here are some candles that you can eat. Out of bananas, or apples, cut and shape some mock candle ends, making them as much as possible like candles that have been burnt down. Fashion some slips of sweet almonds to resemble wicks, and stick them into the mock candles, light for an instant, so as to make their tops black, blow them out again, and they are ready for use. Place in candle sticks, and light when performing. The almond will flame for a few moments, put the candles into your mouth, and chew and swallow them while apparently alight.

Here is a problem to set your friends who are fond of Euclid. A man has three bottles, one with a circular neck, another with a square neck and the third with a triangular neck. He wishes to have a "universal cork" that will fit all three. How should he make it? It is a good plan to cut the figures out of three-ply wood with a fret-saw so that they can see the real problem. Make sure that the diameter of the circle, the base of the triangle and the side of the square are all the same length. It does not seem possible that one cork could fit all these holes, but if you take a cork with the same diameter as the circle and cut it into a wedge shape, the two sides being triangles, you will find that the cork will fit the square, the triangle and the circle.

Sharpen a piece of French chalk to a point, and with it write on an ordinary looking-glass. Polish lightly with a silk handkerchief, and the writing will disappear. Hand the glass to a member of the audience, and request him or her to breathe upon it, and the writing will reappear. Polish the glass again carefully, and the experiment can be repeated.

Take an ordinary paper-knife (of wood or ivory) and bore two holes, about a quarter of an inch apart, right through the blade. At the same distance from the hole nearest the handle bore another hole, but only half way through the blade. Turn the knife over, and a quarter of an inch from the hole nearest the point again bore a hole half way through. Show both sides of the knife to prove that there are three holes, take an ordinary match, and put it in the first hole, turn the knife over, and it will appear coming through the centre hole. When the match is placed in the centre hole and the knife is turned, it will appear to be coming through the end. The knife can easily be bored, and the effect of the trick is much more mystifying to one unacquainted with it than would be supposed from this description.

Place three sticks on a horizontal plane, so that each one shall have one end resting on the plane, and the other end unsupported. To perform this experiment, and to place a weight on the sticks thus poised, proceed as follows:—Hold one stick in a sloping position, with one end resting on a table and the other elevated. On the end resting upon the table rest one end of another stick. Then form a triangle by means of a third stick poised in the same way, i.e. with one end passing under one stick, and the other end above the other. The three sticks will in this manner prove of mutual support to each other, and will not give way even if a tumbler or other weight is placed upon them over the points of contact.

In almost the same manner as described in the preceding trick three knives can be placed with blades only crossed, and with the handles resting upon three wine glasses. The knives not only support each other blade to blade, but upon the triangle at their intersections they will sustain as heavy an object as a filled water bottle.

Now try this experiment. Dip two wine glasses of the same size into a basin of water, and before taking them out, place the brims together, so that they may be withdrawn full, one being inverted on the top or over the other. Then move them very slightly, so that a very small space may intervene between the rims. Take a third glass and drip from it some wine in such a manner that it spreads slowly over the foot of the inverted glass. When the wine has trickled down to the rims of the glasses, the ruddy drops will filter into them and ascend into the upper glass, thus demonstrating the difference in the densities of wine and water.

Take two glasses exactly alike, so that when filled with water they will stand with the rims together on top of one another. Place the glasses in a basin of water, fill them quite full, bring them out together in the position described, and stand in a saucer or basin. Now light some tobacco in a clay pipe, place a handkerchief over the bowl of it, and the stem of the pipe close to the rims of the glasses.

Blow the smoke through the stem, and the water in the top glass will gradually run out into the saucer or basin, and the smoke take its place. The top glass can be emptied of water in this manner.

Fill a glass half full of ale, put a silk handkerchief over the glass, and press it down to the surface of the ale; then gently fill the glass up with water, draw up the handkerchief, and the water will remain upon the ale, but will not mix with it.

Fill a glass, and lay a piece of thin card or paper over the top, dexterously turn the glass upside down, and place it upon the table, which must be level, then draw away the paper or card, leaving the water in the glass. It will be impossible to remove the glass from the table without spilling the water. Do not perform this trick in a drawing-room.

Have handy three strips of paper, each two or three feet in length by one inch in width, paste, and a pair of scissors. Paste the ends of the first strip of paper together. Twist the second strip of paper once, and paste the ends of that together. Twist the third strip of paper twice, and paste the ends of that together also; i.e. make three paper loops. Exhibit the first loop, and remark that the obvious effect if you cut it in half, stripwise, will be to make two loops. The loops should then be cut. Now pick up the second loop and remark that you are going to do the same with this loop. Cut the loop of paper, and a loop twice the size will be produced. Now pick up the third loop, and cut that in the same manner, and two loops, one inside the other, will be produced. In the case of the loop with the double twist, it will require a little dexterity to keep this twist masked, especially when cutting the twist. The loops are, of course, prepared before the spectators enter the room.

Three walnut shells are laid upon a table that has been covered with a cloth, a small ball or pea made of india-rubber is placed under the centre one, and the other two are shown not to be covering anything. Ask which shell the pea shall appear under, and being told, push forward the other empty shell along the table about three inches with the first and second fingers. Do the same with the one that is covering the pea, and as it is moved forward, the pea will come out behind it as a natural effect. As it comes from under the shell cover it with the first and second fingers which are held together, then move the third shell forward with these two fingers, and in doing so place the pea underneath it. This is not at all a difficult trick to perform, very little practice being required, and although the onlookers may be very close, they will rarely see how it is done.

You may have seen someone smoking a pipe or cigarette who is able, after inhaling the smoke, to send it back in the form of beautiful rings into the air. In a still atmosphere these rings will remain quite perfect and float about for some while. It is really quite easy to make a box with which you can produce smoke rings as fast as you wish. Get a well-made card or wooden box which is rather longer than it is wide. One end of the box should be removed altogether and across this stretch a piece of cloth, fixing it with gum or glue. At the opposite end cut a round hole about an inch across. You are now ready to start making smoke rings. Get a piece of thick brown paper, light this for a moment and then blow out. The paper, which will now be smouldering and giving out a lot of smoke, is pushed in through the hole at the end of the box. Of course, in a moment the box is filled with smoke. All you have to do now is to give the cloth at the other end of the box a series of smart little taps. With every tap there will issue from the hole a perfect smoke ring, and you can send these out as fast as you like, one after the other. Sometimes one ring will overtake another and you get a very pretty effect. The smoke rings will continue to come out as long as there is any smoke left in the box.

It is easy to illustrate the importance of stream-lining, by laying a tintack head downwards on a penny and covering the whole with a piece of tissue paper about seven inches square, allowing the point of the tack to project. If the ends of the paper are now twisted round in a tail and the whole is thrown up to the ceiling, the tack will stick, the weight of the penny breaking away the paper which then falls to the ground.

If you wish to talk about Einstein and relative movement, prepare a dining-room table with a hairy cloth. You can then play a good game of billiards by using ping pong balls and long pencils as cues. The friction of the hairs helps you to perform many difficult billiard strokes.

Should you like to talk about the effect of the moon upon tides, the force of gravity and other learned matters, borrow a shilling, place a small piece of paper on top of it and allow the two to fall together. Both shilling and paper will drop at the same speed, showing that it is the air alone which usually prevents the paper from reaching the ground at the same time as the shilling. This is nothing to do with the friction between two sheets of paper when pressed tightly together and which produce electricity when drawn smartly apart.

An amusing " snake " can be made by drawing a spiral upon a piece of paper about three and a half inches in diameter, the lines being a quarter of an inch apart. If you cut round the spiral and put a pin through the top, the whole will rotate when held over a flame or draught.

An apparently miraculous sleight of hand trick is made simply by the aid of a round cork and a long hair. If this hair is attached to the cork by pushing in the ends with a match, leaving a loop about two inches long, the hair can be slipped over the middle finger and the cork made to vanish by being dropped behind the outstretched hand.

An experiment which is supposed to show the manner in which absolutely pure materials are electrically unable to enter into violent change is performed by attempting to light a piece of lump sugar with a match. It is only necessary to touch the sugar some time beforehand with a lighted cigarette, to find that the slight adulteration greatly assists combustion. Absolutely dry coal which has been desiccated by the aid of phosphorous pentoxide will seldom burn even when raised to red heat, while pure sulphuric acid and pure zinc may show virtually no interaction.

Here is a very effective trick on entering a room. The performer, with hand covered by his hat, rubs a polished pencil, sharpened towards the side instead of in the usual way, sharply down the side of the door. The pencil will adhere to it, and a hat with a flat brim can be hung upon the pencil.

If two glasses are placed one within the other, the inner glass can be removed by blowing into the gap. This is a good demonstration of the power of a rapidly moving stream of air.

Another very simple trick is to make four nicks in the edge of a halfpenny; it will then be found to adhere to most walls.

Some words of warning in conclusion might well be remembered by every experimenter. If your test is in the nature of a trick, never explain the nature of the result until you are sure of it yourself. Be exceedingly careful with every chemical you handle, for this is one sign of a scientifically-trained mind.

Nearly every invention, experiment, or trick, depends for its psychological effect upon the order in which the various operations are performed. What is a perfectly simple commercial process may very easily appear magical if the order of each stage is apparently reversed or if the necessary steps leading to the final result are sometimes omitted.

MISCELLANEOUS EXPERIMENTS AND TRICKS

Miracles are usually perfectly ordinary events, which, for the moment, are not understood. If after every experiment the explanation is sought, and if you further remember that no result can ever completely be explained, you will have prepared your mind to imagine how a better result can be obtained, or even how some useful purpose may be invented.

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